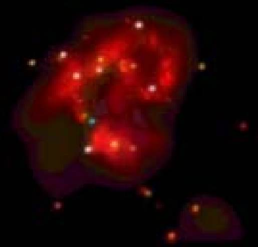
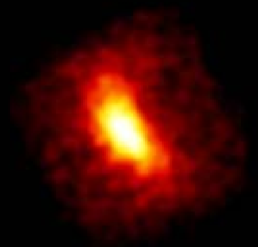
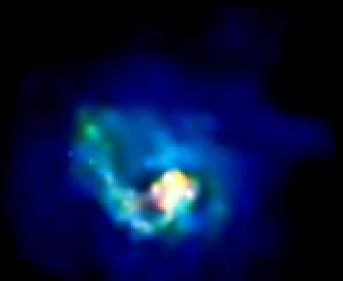
Constellation X

The Constellation X-ray Mission

Presentation to the SEUS

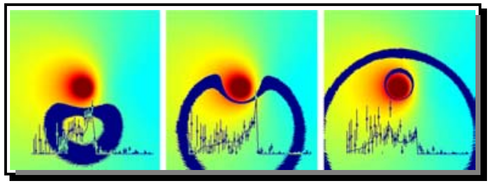


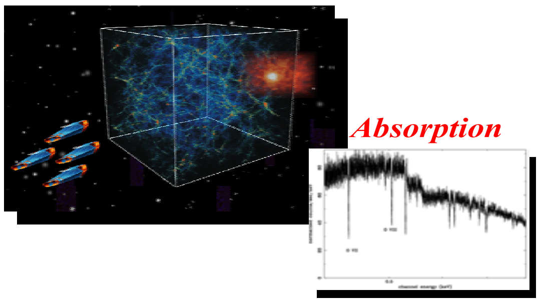




Elizabeth Citrin
NASA/GSFC

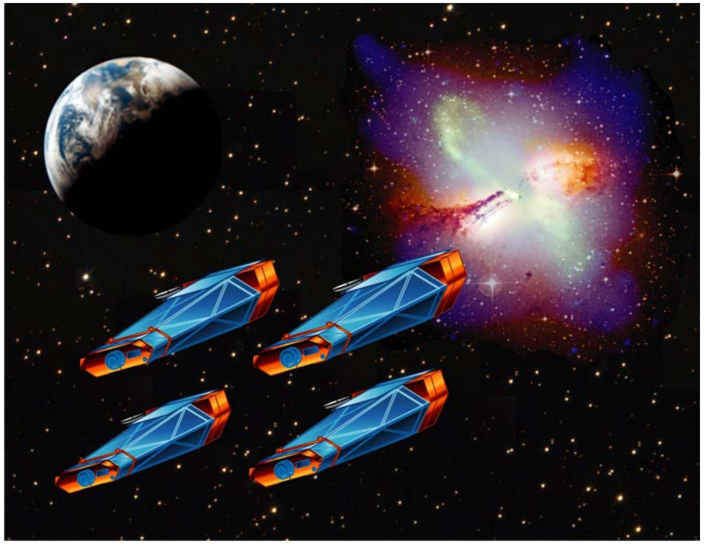
Constellation-X Key Features

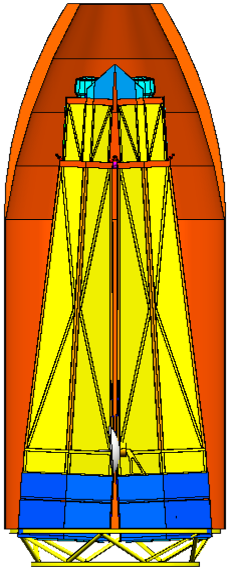




- **Large area X-ray spectroscopy to study:**
  - **Effects of strong gravity near supermassive black holes**
  - **Nature of dark matter and dark energy**
  - **Formation of supermassive black holes**
  - **Lifecycles of energy**

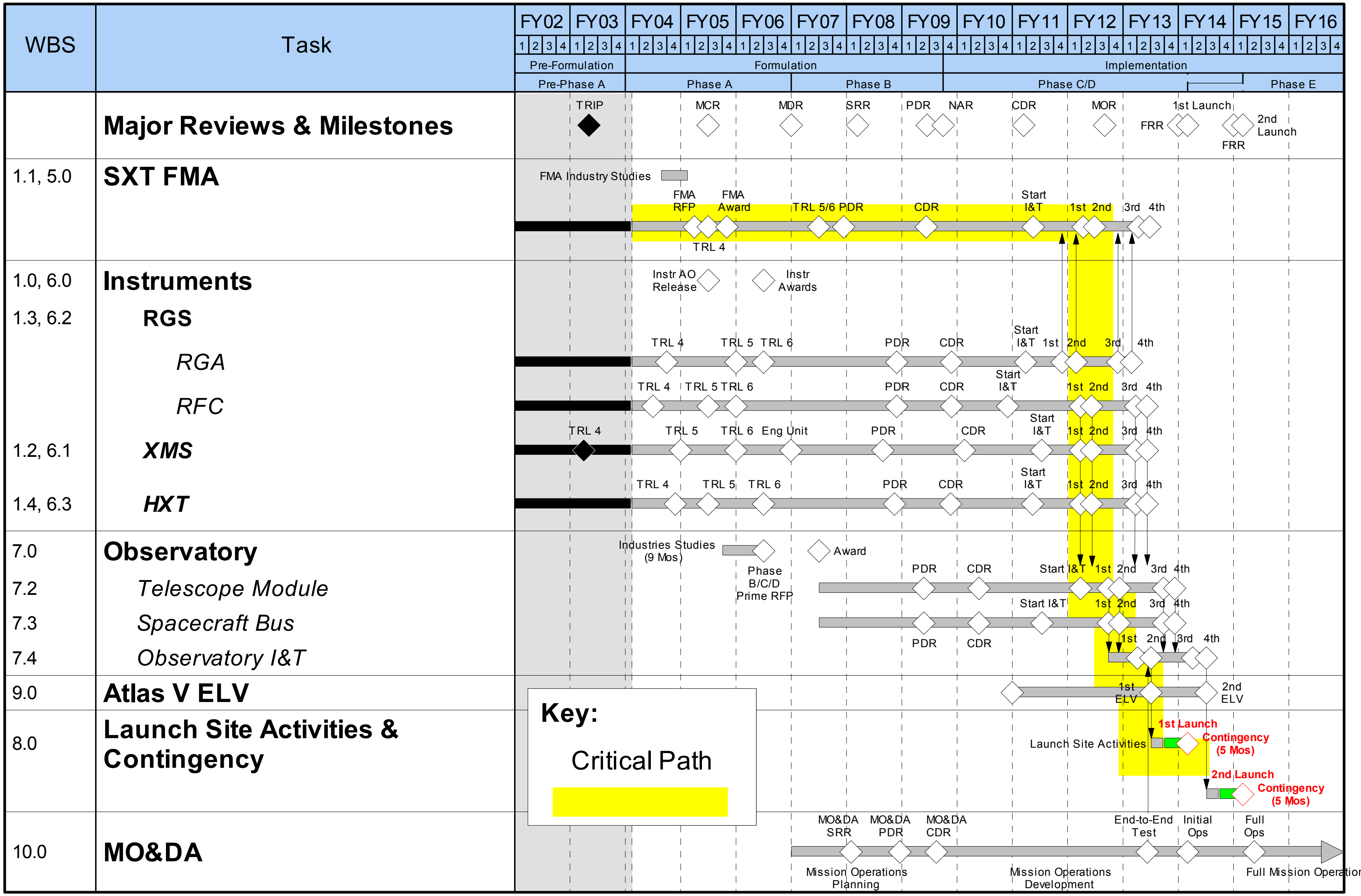
- **Mission Approach:**
  - **Four satellites launched two at a time on Atlas V class vehicle**
  - **L2 orbit for high efficiency, simultaneous observations**
  - **Modular spacecraft bus and telescope**
- **Schedule:**
  - **Launches in 2013 and 2014**





Constellation-X Mission Summary Schedule

4/03 (POP 03-1)



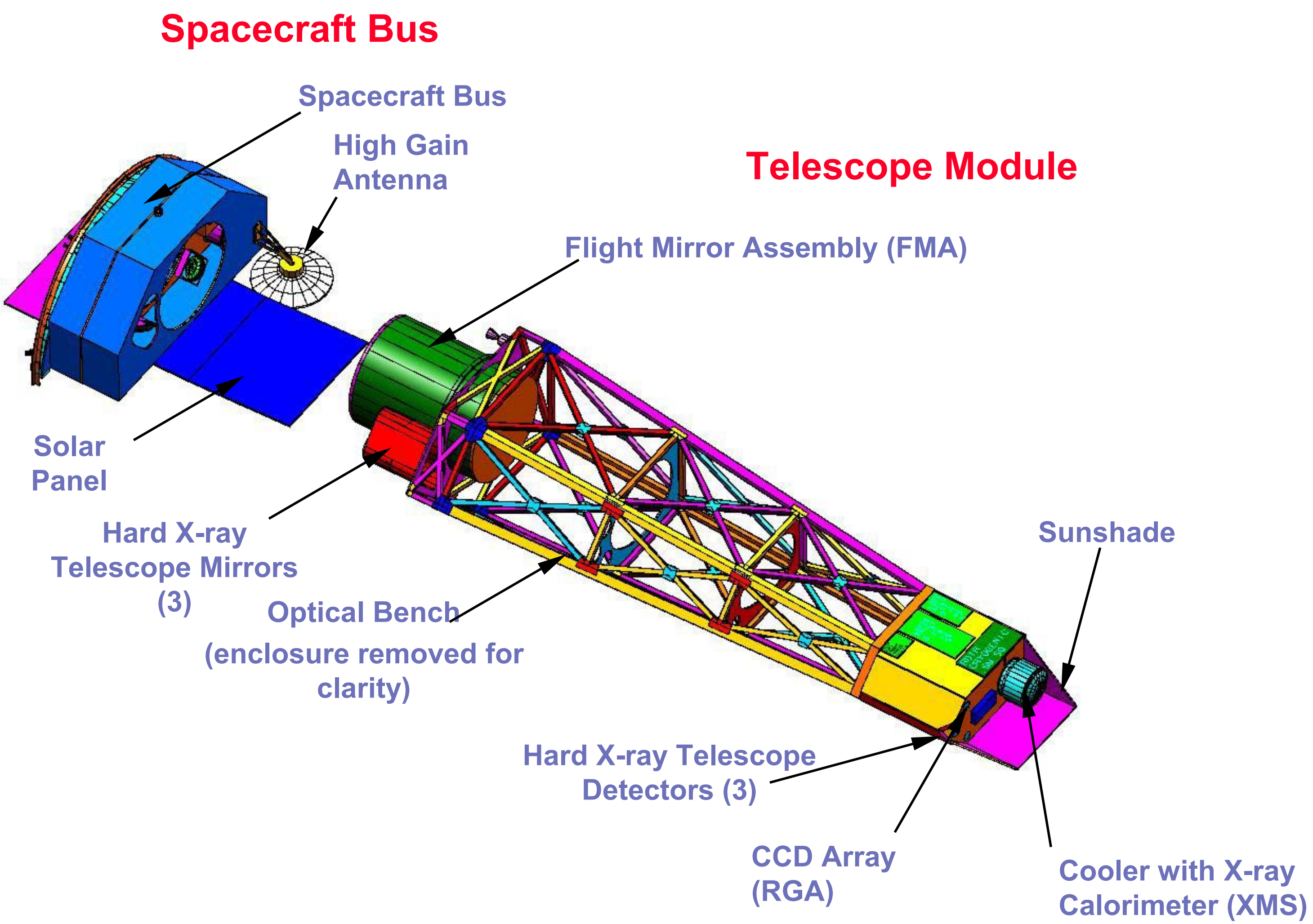
The Recent Budget Picture

- **FY04 funding for the mission reduced significantly in the fall ($23.5M to $10.1M)**
  - Project immediately reduced staffing, put all major procurements on hold
  - Funding allocations were revised based on the following principles:
    - Keep core technology development teams in place
    - Optics (longest lead, most critical mission technology) has funding priority
    - Only FY04 was re-planned
- **Recently released FY05 budget provides approximately same funding for Constellation-X as FY04**
- **Five-year budget projection is well below levels anticipated at BEI new start**
  - Problems in FY06 may required severe reduction in FY05 costing to maintain any activities in FY06
  - Ramp up after FY06 is much slower than originally planned
  - Total budget guideline through FY09 is ~ 30% of anticipated levels
  - Project is reassessing launch dates; first launch > 2016

Project Response

- Work with HQ, FST, technology teams and the scientific community to develop the best mission strategy within our constraints
- Work with FST and technology teams to:
  - Revisit mission configuration including launch vehicle options and packaging strategies
  - Review current requirements and goals in view of progress to date and recent science developments; update as appropriate
  - Identify and pursue promising opportunities—increased capability and/or reduced risk and cost
- Explore broader international approaches to advance the mission and to achieve the science goals

Mission Reference Configuration

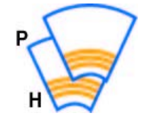
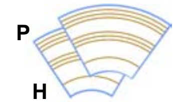


Constellation X
The Constellation X-ray Observatory

Spectroscopic X-Ray Telescope (SXT) Technology Development

IPT Lead: Dr. Rob Petre
Organizations: GSFC /MSFC /SAO

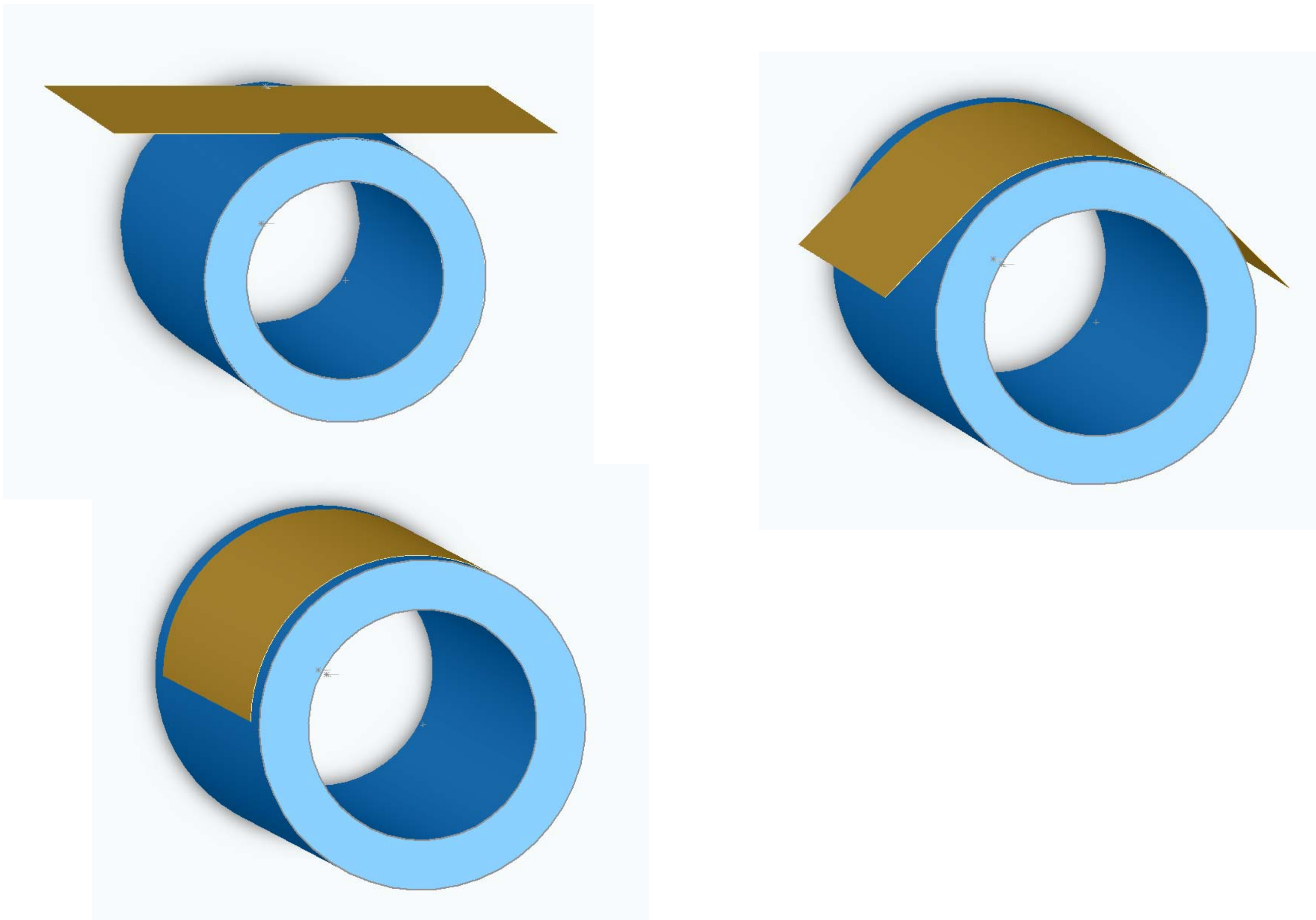
Segmented X-ray Mirror Development Process

	Optical Assembly Pathfinder		Engineering Unit	Mass Production Pathfinder	Prototype Pathfinder	Prototype
	OAP #1	OAP #2				
Configuration						 Industry Development
Module Type	Inner	Inner	Inner	Inner	Outer	Sector (2 Outer & 1 Inner)
Housing Material	Aluminum	Titanium	Titanium/composite	Titanium/composite	Titanium/composit e	Titanium/composite
Focal Length	8.4 m	8.4 m	8.4 m	8.4 m	10.0 m	10.0 m
Reflector Length (P&H)	2 x 20 cm	2 x 20 cm	2 x 20 cm	2 x 20 cm	2 x 20-30 cm	2 x 20-30 cm
Nominal Reflector Diameter(s)	50 cm	50 cm	50 cm±	50 cm±	160 cm± 120 cm± 100 cm	160 cm± 120 cm± 100 cm± 80cm±, 30 cm±
Goals	▪ Align 1 reflector pair (P&H) ▪ Evaluate mirror assembly design, alignment and metrology	▪ Align 1 reflector pair ▪ Evaluate reflector ▪ Evaluate mirror bonding	Requirements: ▪ Align one reflector pair to achieve <12.5 arcsec ▪ X-ray test, vibration test (Q4 of FY04) Goals (Q2 of FY05): ▪ Replicate 3 mirror pairs using a single replication mandrel ▪ Align up to 3 reflector pairs to achieve <12.5 arcsec ▪ Environmental test	▪ Align 3 reflector pairs ▪ Evaluate tooling and alignment techniques for mass production ▪ X-ray test	▪ Flight-like configuration outer module ▪ Environmental and X-ray test ▪ Largest reflectors	▪ Demonstrate largest and smallest diameter reflectors ▪ Demonstrate module to module alignment ▪ Environmental and X-ray test
TRL	TRL 3		TRL 4		TRL 5/6	TRL 6

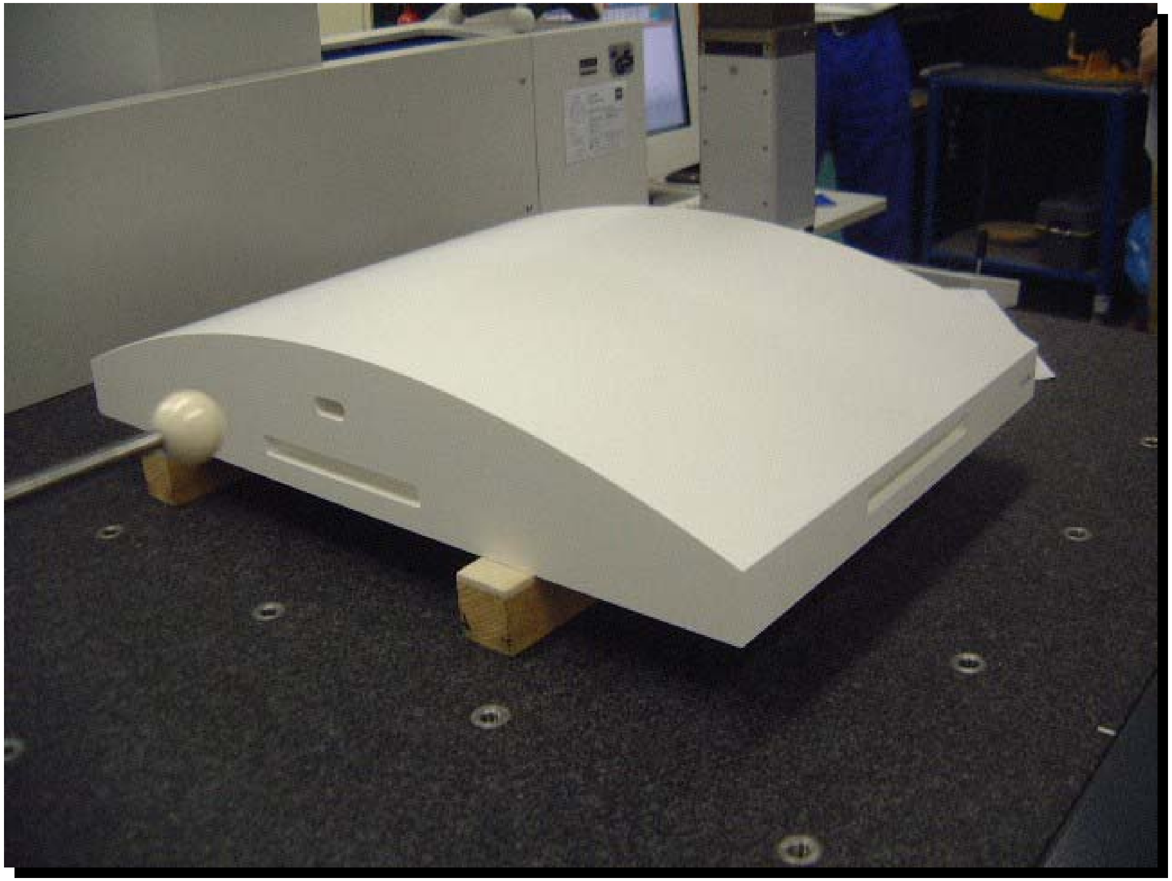
Progress in SXT Technology Development

- **Identified key drivers to achieving reflector figure: precision-figured forming mandrel, and the substrate slumping process**
  - Improved conformance of substrate figure to forming mandrel figure (within 0.2 μm RMS)
  - Demonstrated good reproducibility of glass substrates (within 0.5 μm)
  - Ongoing improvements to the slumping process include reducing contaminants, improving slumping thermal uniformity, and thermal/structure modeling of the process.
- **Demonstrated epoxy replication preserves the low order figure while reducing mid to high frequency errors**
  - Reduced epoxy stress by reducing epoxy thickness and segmenting epoxy layer into axial strips (5um epoxy thickness)
  - Demonstrated microroughness requirement can be met (4 Å rms)
  - Ongoing improvements include reducing dust during epoxy application, and reducing epoxy thickness further
- **Developed optic assembly pathfinder – testbed to investigate mirror mounting/bonding/assembly, alignment, and test.**
  - Titanium housing to provide good CTE match to the reflectors
  - Developing reflector alignment and bonding methodology using the Centroid Detector Assembly (CDA)
- **Completed the SXT X-ray test infrastructure in MSFC's 100-m Stray Light Facility – will be used to perform tests on the optic assembly pathfinders.**

The Slumping Process

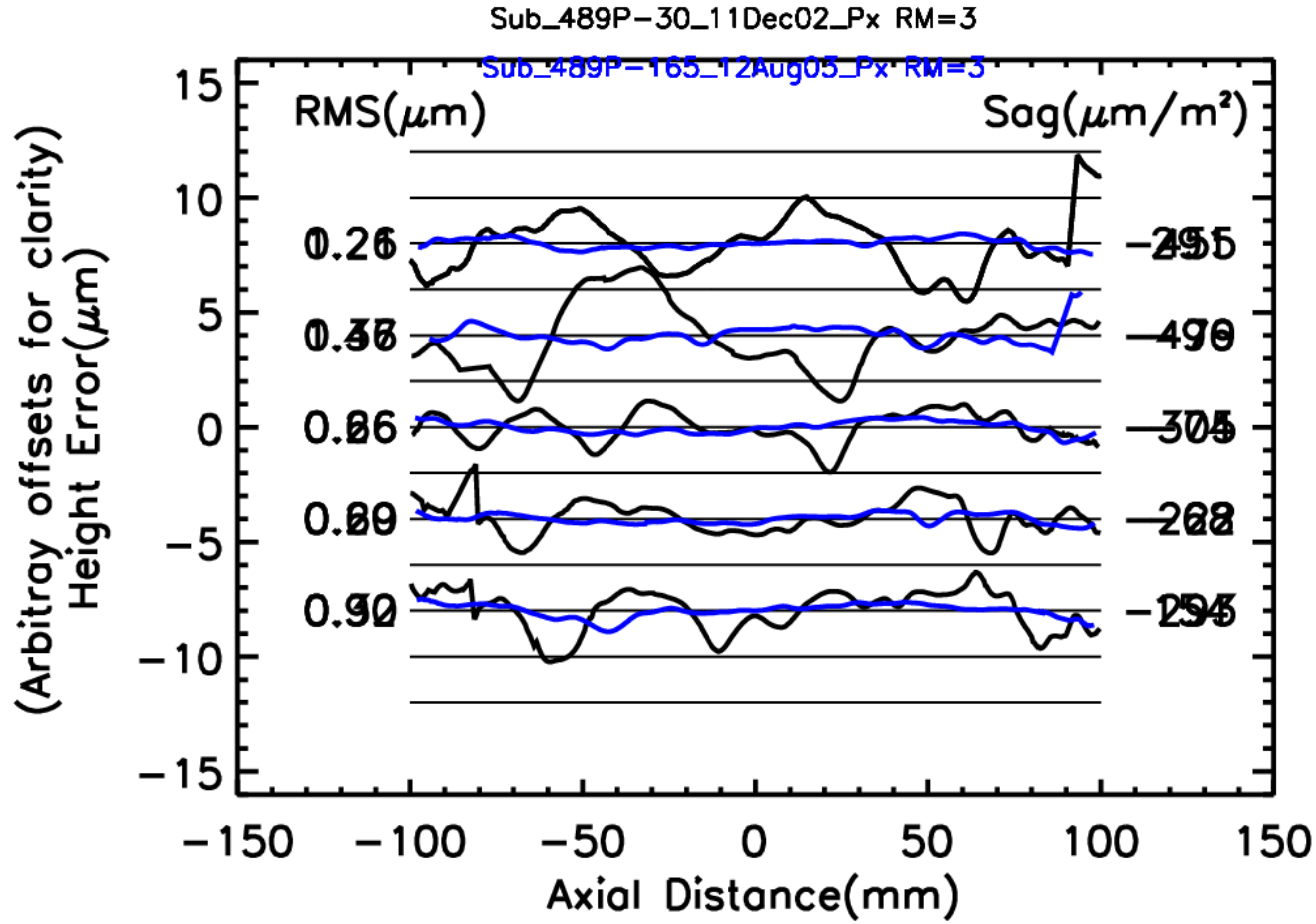


5” Forming Mandrel From Fabricated by Schott and Zeiss



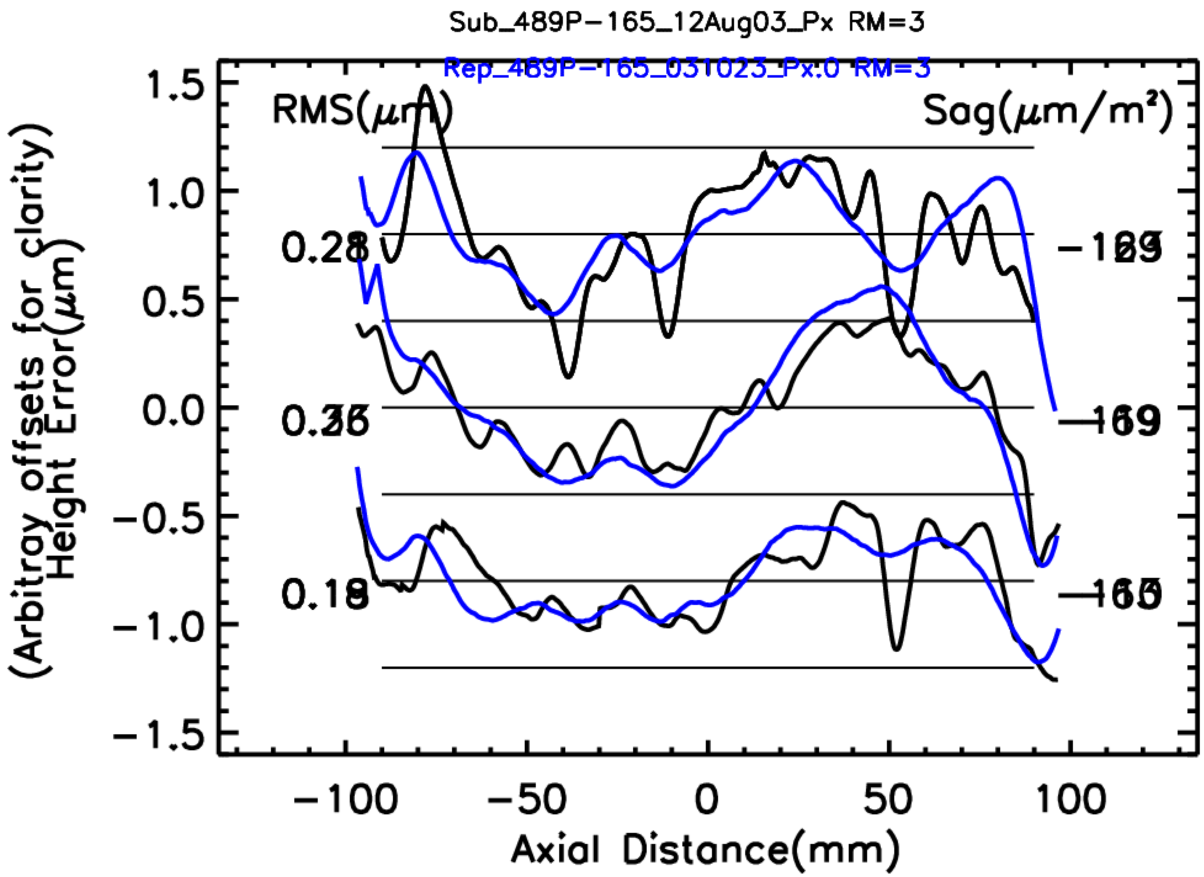
Mirror Quality Improvement

Mirror Quality Improvement from Dec 2002 (Black: ~1.0μm) to Aug 2003 (Blue: ~0.2 μm)



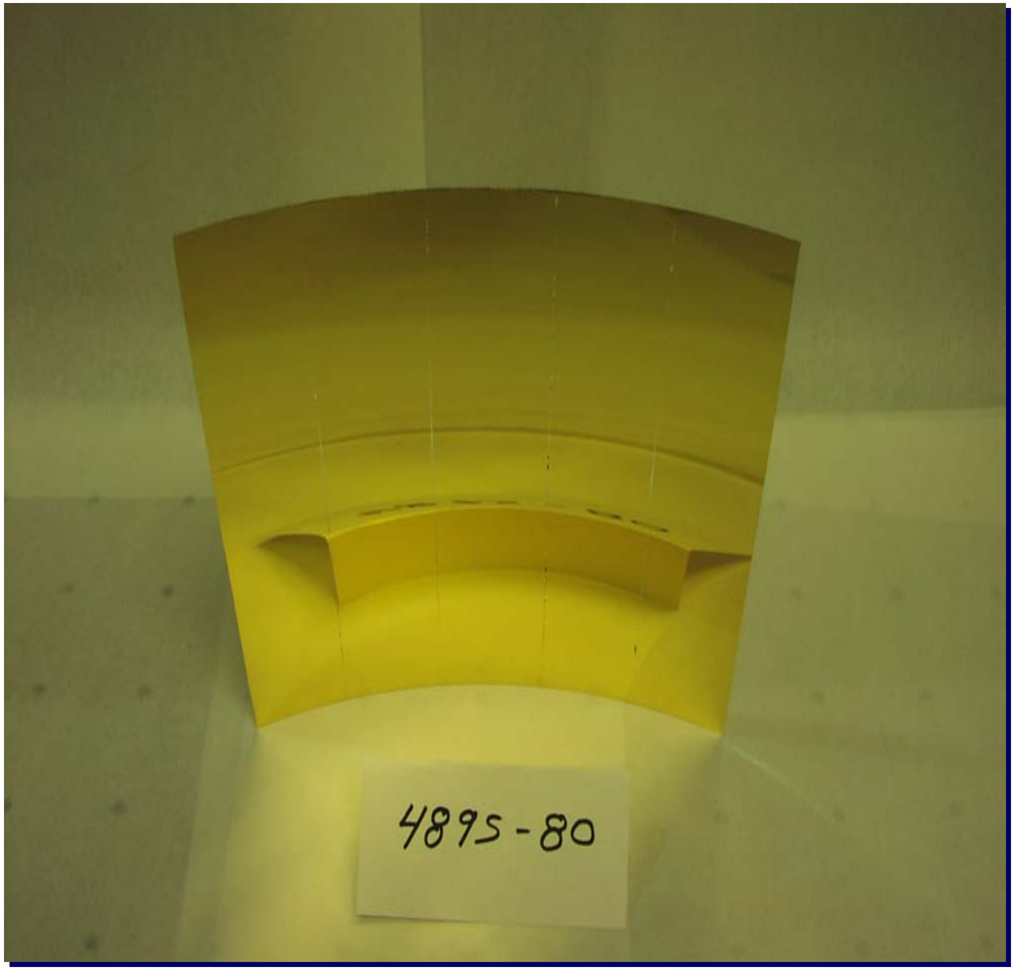
Replication: Smoothing out the High Frequency Ripples

Replication: Smoothing out the high frequency ripples
Black: before replication
Blue: after replication



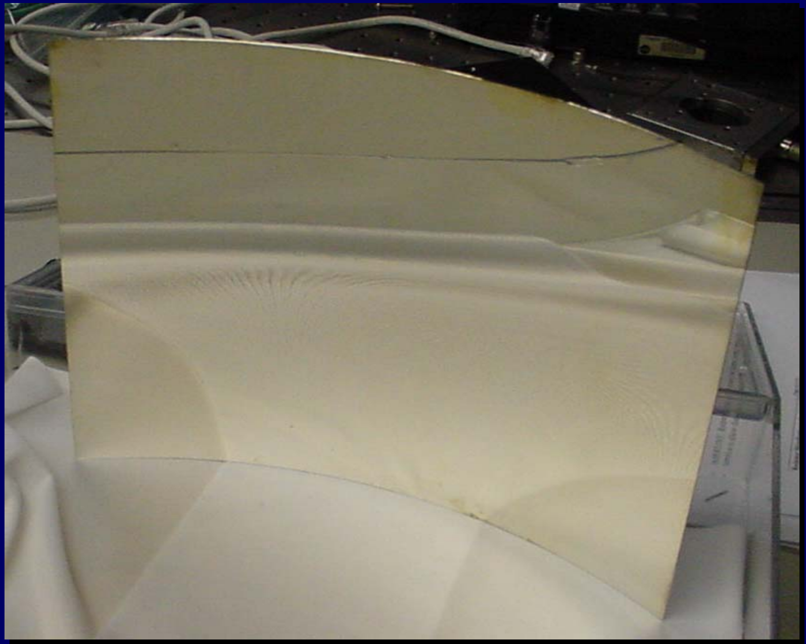
Picture of a Finished Reflector

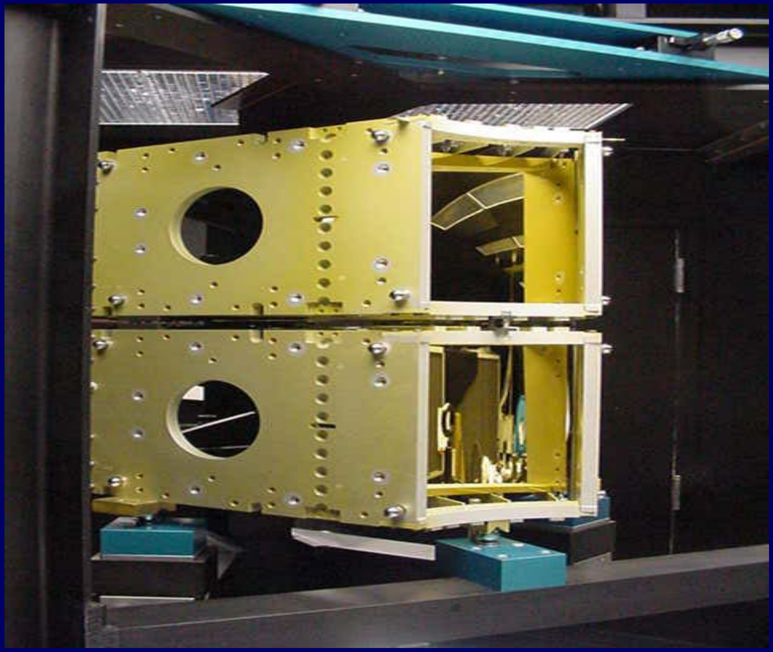
Picture of a finished reflector:
400μm glass+5μm epoxy+0.2 μm gold



Formed 50 cm Diameter Glass Reflector Segment

Optic Assembly Pathfinder (OAP) Unit





Constellation X
The Constellation X-ray Observatory

X-Ray Microcalorimeter Spectrometer (XMS) Technology Development

IPT Lead: Dr. Richard Kelley
Organizations: GSFC /NIST /SAO

Microcalorimeter Technology Roadmap

Element	State-of-the-Art	Array TRL 4	Readout TRL 4	TRL 5	TRL 6	Flight Requirement
Array Size	32	5 x 5	24 pixels on 4 chips	8 x 8	32 x 32	32 x 32
Channels read out simultaneously	32	2	24	16	96	1024
Fabrication				Reliable superconducting leads, parasitic R < 5% of normal R	High-density microvias and bump-bonds	
MUX Scale	None	None	2 x 12	2 x 8	3 x 32 goal	32 x 32 goal
MUX Speed	None	None	5 MHz	10 MHz	20 MHz	20 MHz
Pixel Size	0.64 mm	0.25 mm	0.4 mm	0.25 mm	0.25 mm	0.25 mm
System Noise				< 2 eV	< 1 eV	< 1 eV
Energy Resolution	4.8 eV @ 6 keV	10 eV @ 6 keV			4 eV @ 6 keV	
Testing					Radiation, Environmental	
Technology gates				♦	♦	

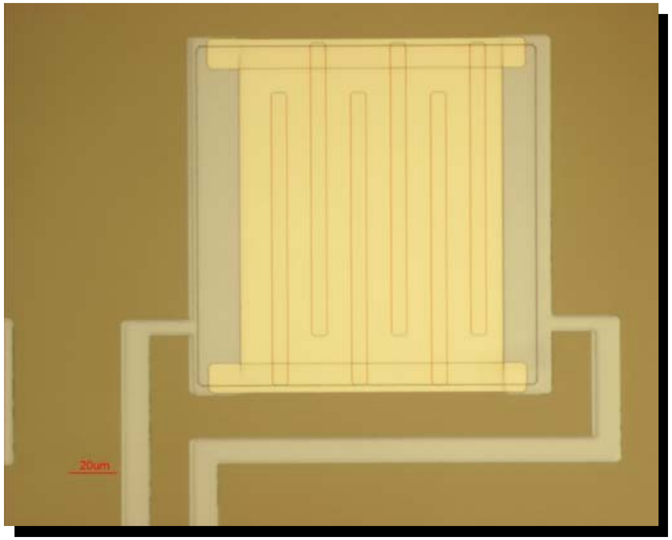
X-Ray Microcalorimeter Detector

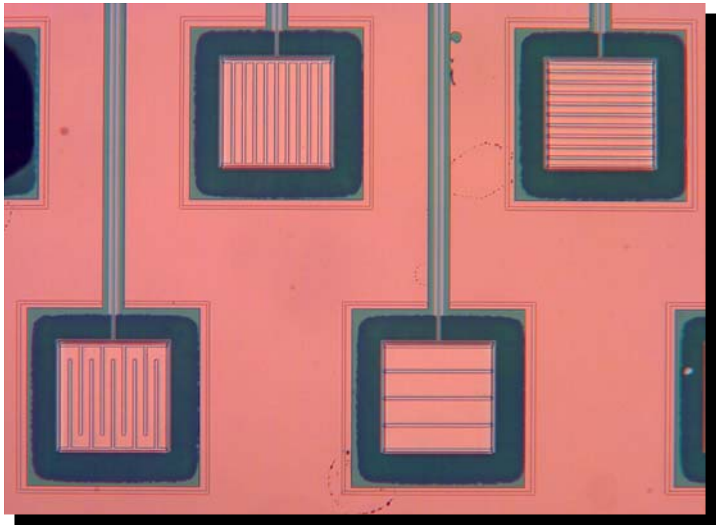
Principal Areas of TES Progress:

- Characterization and modeling of intrinsic noise
- Fabrication of 8x8 arrays
- Multiplexing X-ray TES calorimeters

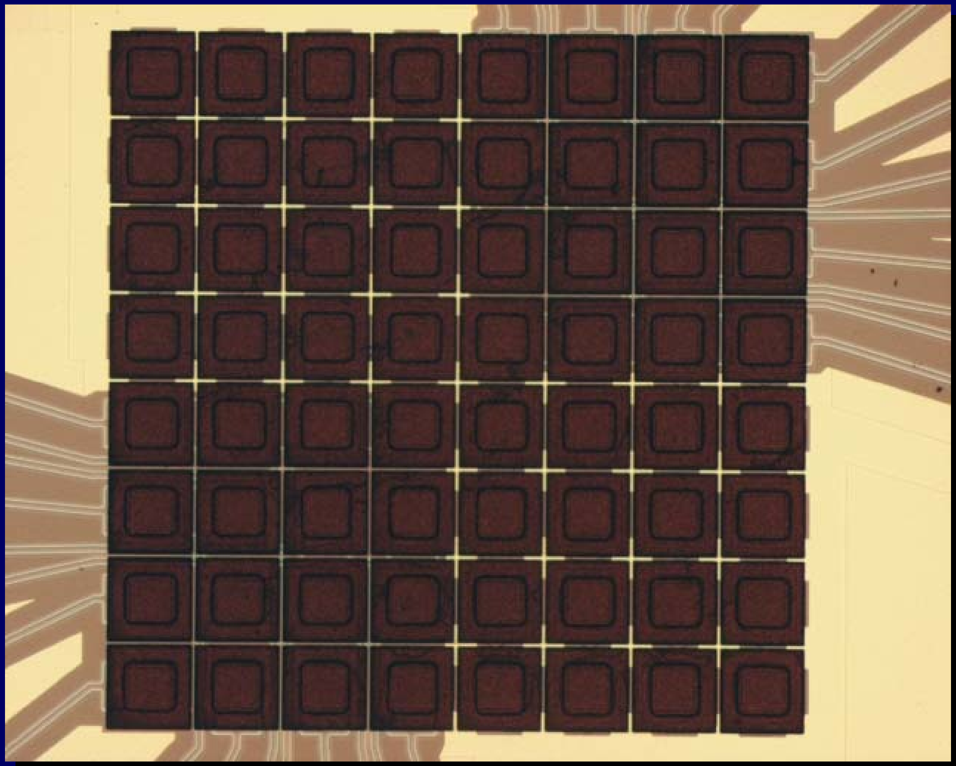
Dependence of Detector Noise on Geometry

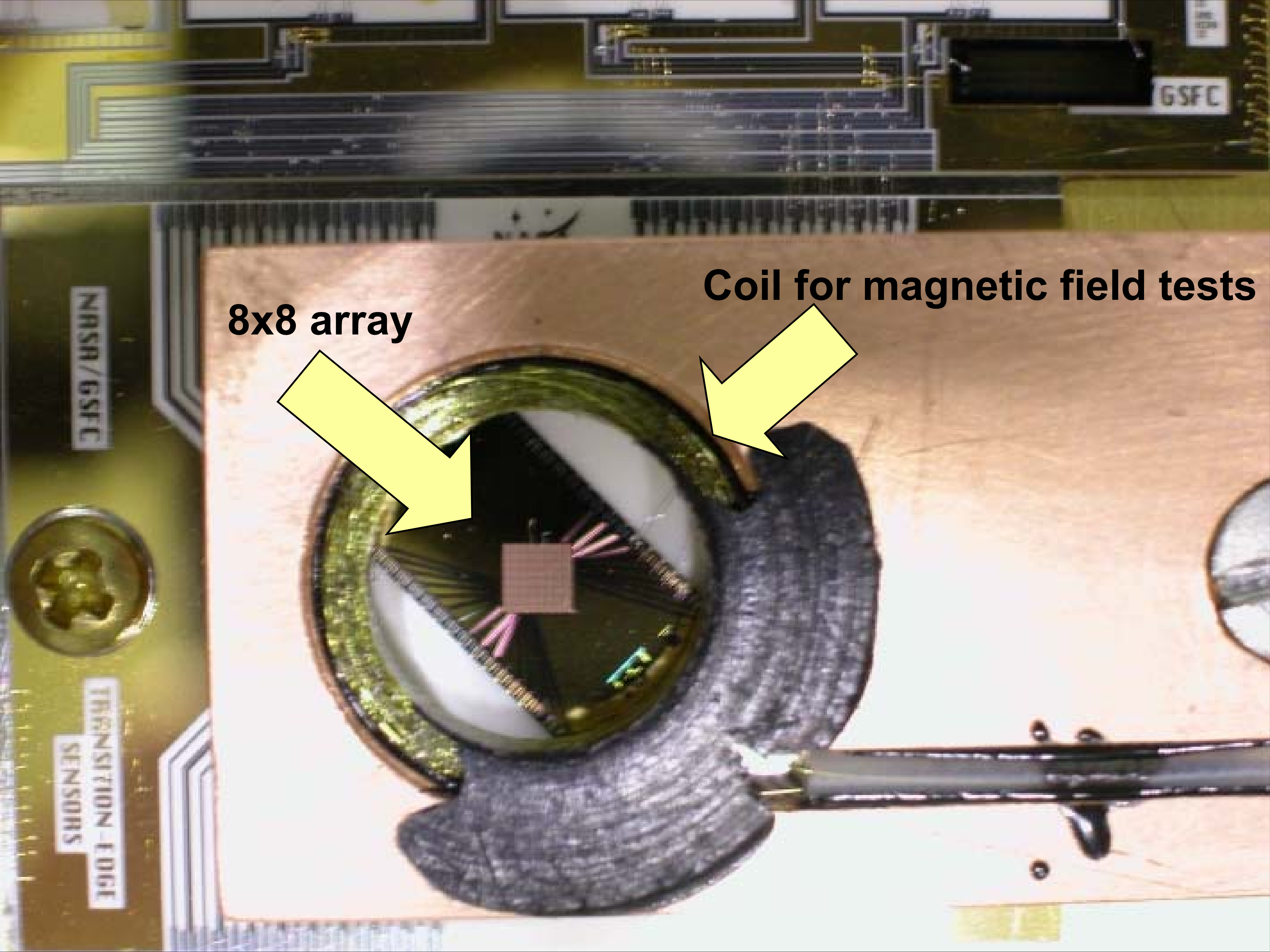
- **NIST, GSFC, and other TES research groups have demonstrated that depositing normal metal stripes perpendicular to the current flow reduces the excess noise, at the cost of a (sensitivity). Reducing heat capacity can compensate for the lost sensitivity in an ideal device. Optimization is still in progress, but it will likely hinge on the thermalization properties of the x-ray absorber. Careful characterization of the thermal properties of low-heat-capacity absorbers will be done over the next several months. Extensive noise characterization done at NIST and theoretical modeling done at GSFC promise to aid in the design optimization.**





- First 8x8 arrays produced, with high-efficiency, high-fill-factor absorbers
- Can continue optimization studies within these arrays

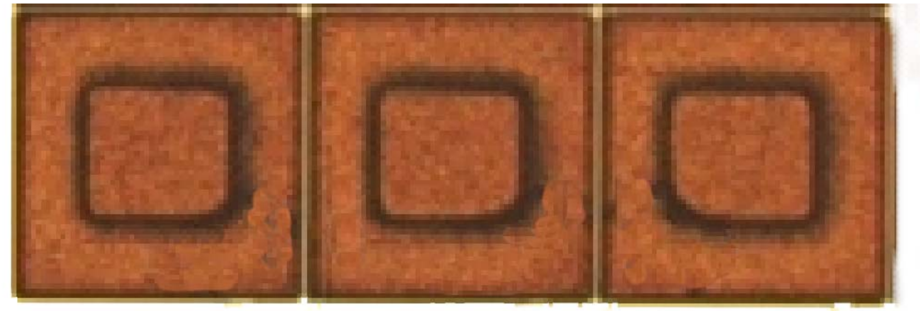


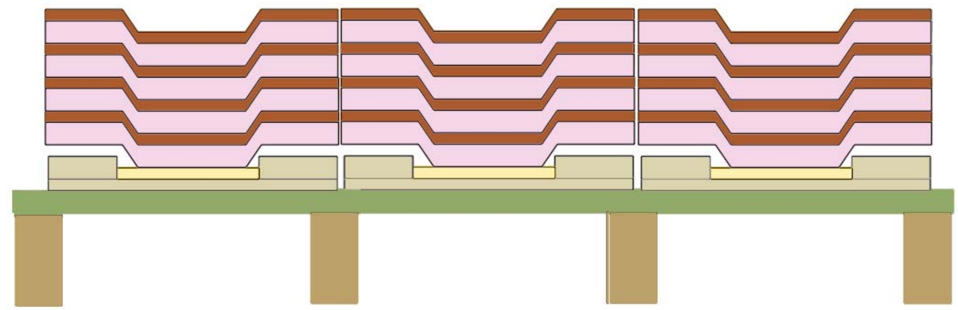


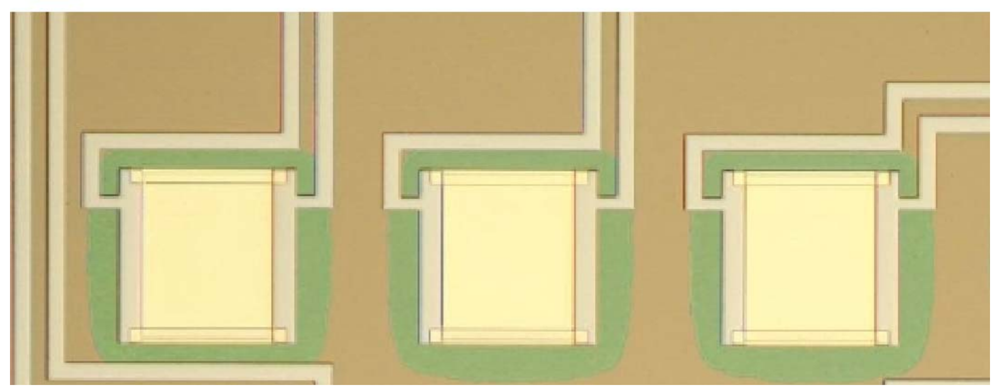
8x8 array
Coil for magnetic field tests
GSFC
NASA/GSFC
TRANSITION-EDGE
SENSORS

Compact Pixel Overview

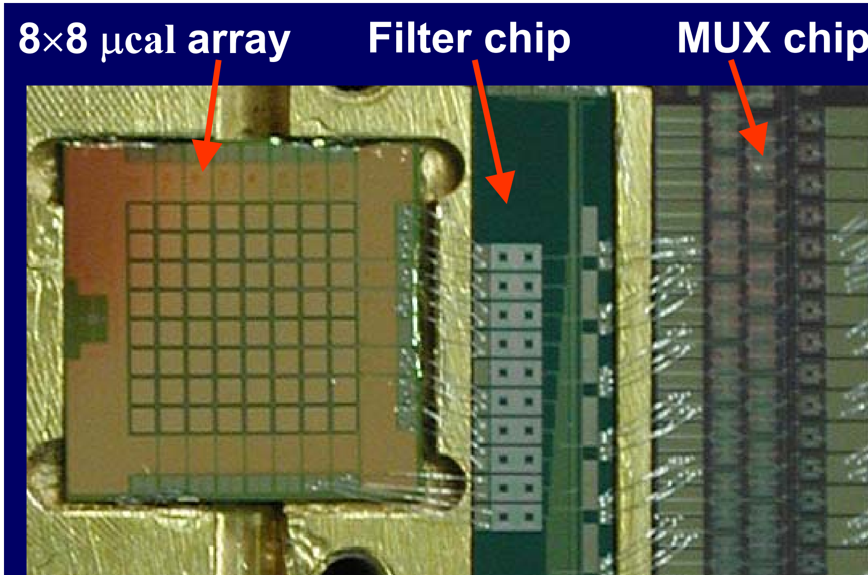
- **Overhanging absorbers**
  - 4 layers of Bi, thickness: 2.25 or 2.0 microns
  - 4 layers of Cu, thickness: 0.2 microns
  - High absorption efficiency
  - Good thermal conductivity
- **TES calorimeters suspended on SiN membranes**
- **Reducing the heat capacity will require using less Cu**
- **Internal thermal fluctuation noise that might result from removing Cu can be mitigated by making the device slower**
- **Overall optimization with regard to resolution, efficiency, and count rate will be determined**

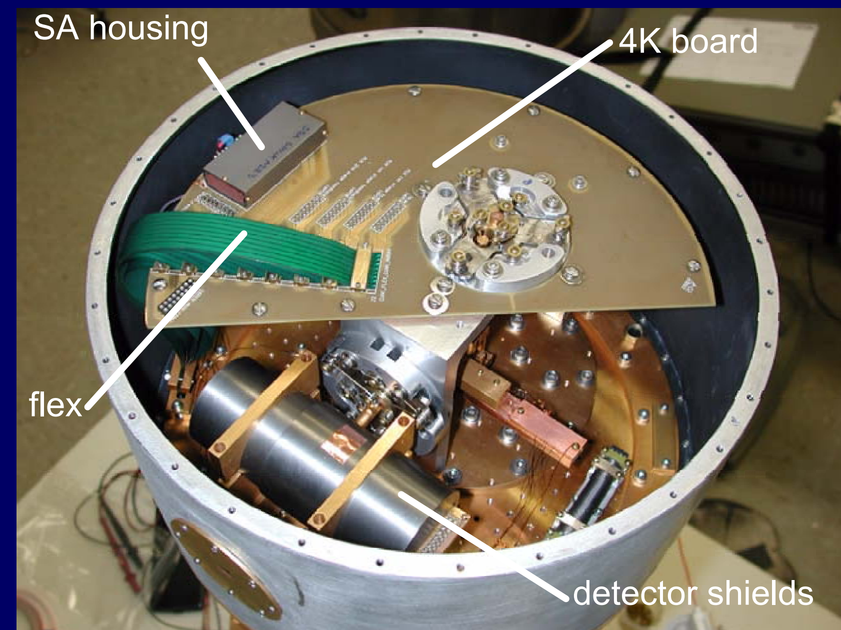


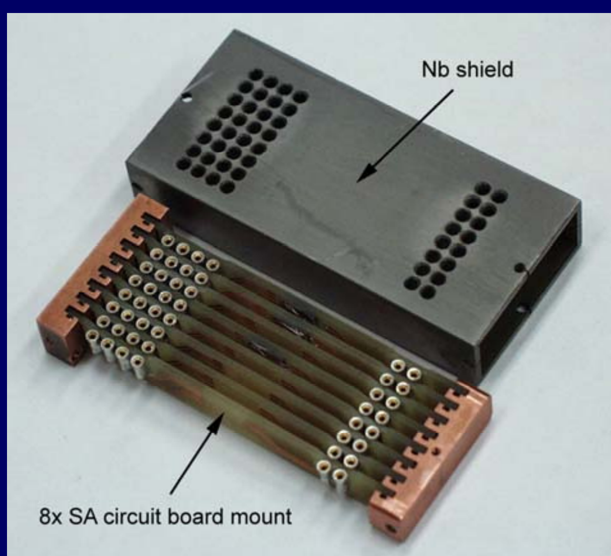




NIST 2x10 Multiplexed Test Facility







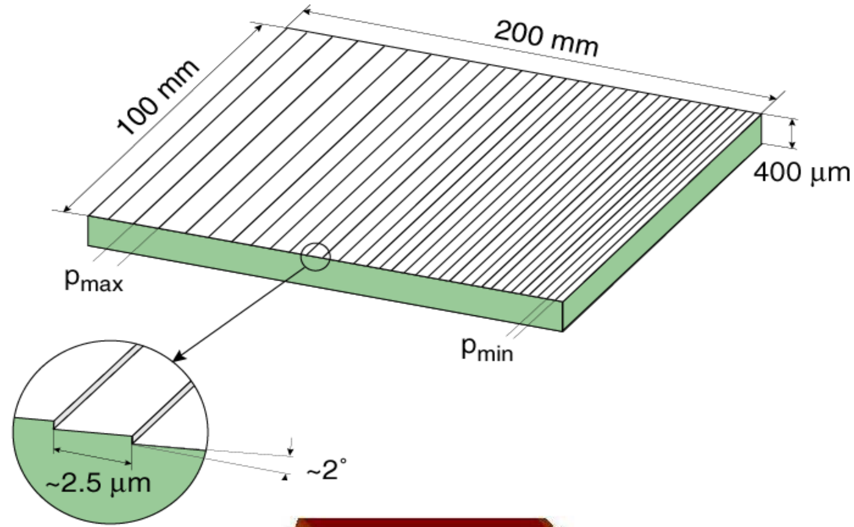
Constellation X
The Constellation X-ray Observatory

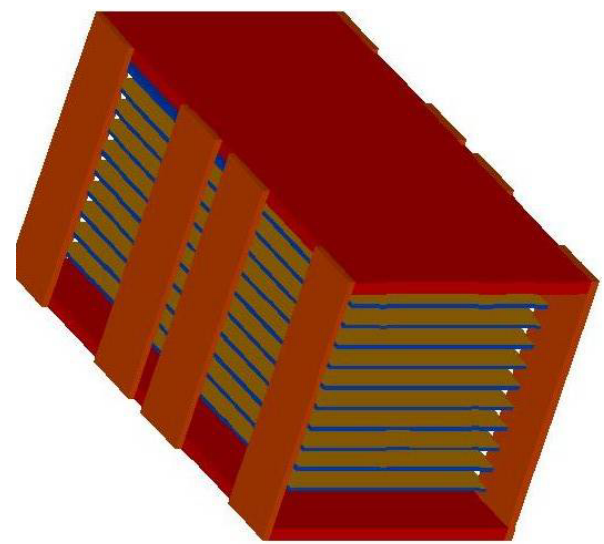
Reflection Grating Spectrometer (RGS) Technology Development

IPT Lead: Dr. Kathy Flanagan
Organizations: Columbia University /MIT /University of Colorado

Reference Grating Concept

- **Substrates**
  - **Silicon or glass sheets, 100x200 mm**
  - **Thickness 0.4-1.0 mm, flatness ≤ 2 arcsec**
- **Gratings (~1000/array, identical)**
  - **Patterned on substrates**
  - **Period is 2.5 microns (407 l/mm)**
  - **Grating has 5% period variation (chirp)**
  - **Groove blaze = 0.6º, roughness ≤ 0.5 nm**
- **Modules (~100/array, identical)**
  - **Hold ~10 gratings in fan-out configuration**
  - **Assembly alignment accuracy ≤ 2 arcsec**
- **Off-plane concept is also modular**
  - **Much tighter period: 0.17 microns (5800 l/mm)**
  - **Grooves will have *radial* arrangement**





RGA Technology Development Roadmap Summary

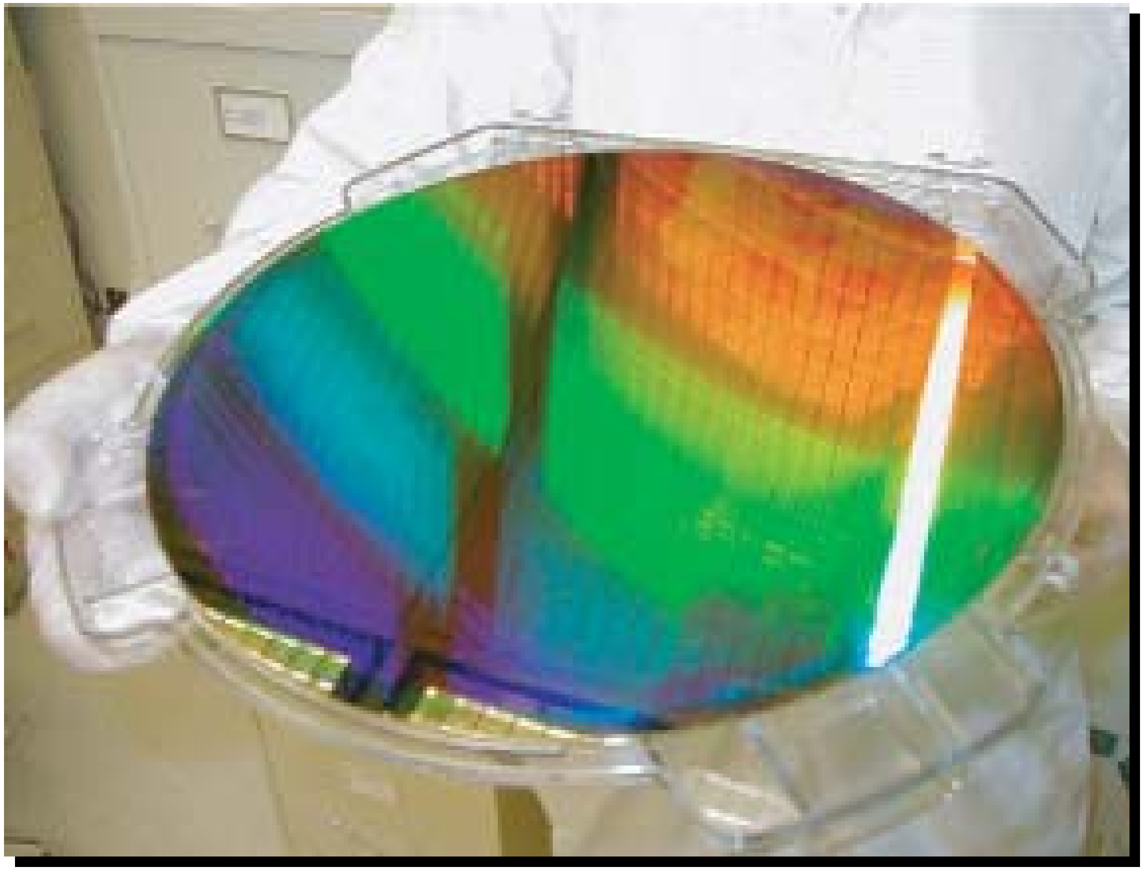
Parameters	State-of-the-Art XMM-Newton	Grating Fab Demo	Large Area Grating	Demo Assembly	Grating Chirp	Grating Module Engineer Unit	Grating Module Flight Unit
Substrate Flatness	<2 arc sec	~30 arc sec (4”)	<2 arc sec	<2 arc sec	<2 arc sec	<2 arc sec	<2 arc sec
Grating Size	200 x 100 mm	20 x 20 mm	140 x 100 mm (70% flight size)	200 x 100 mm (nom. flight size)	(200 x 100 mm)	(200 x 100 mm)	(200 x 100 mm)
Grating Mass/Unit Area	0.6g/cm^2	—	—	0.2g/cm^2	—	0.2g/cm^2	0.2g/cm^2
Groove Form	0.7 deg blaze	0.7 deg blaze	0.6 deg blaze	NA	0.6 deg blaze	0.6 deg blaze	0.6 deg blaze
Ruling Density/Variation	646 l/mm / 7%	500 l/mm / NA	407 l/mm / 0%	NA	407 l/mm / 5%	407 l/mm / 5%	407 l/mm / 5%
Groove Fabrication Process	Epoxy multi-gen replication of mechanically ruled master grating	Interference lithography & anisotropic etch Si (111) plane facet	Scanning Beam Interference Lithography (SBIL) Si (111) plane facet	NA	Variable Period (VP) SBIL pattern & anisotropic etch Si (111) plane facet	VPSBIL pattern & anisotropic etch Si (111) plane facet	VPSBIL pattern & anisotropic etch Si (111) plane facet
Ass'y Level & Properties	Gratiing Array	Single grating	Single grating	Module	Single grating	Module	Module
Gratings per Module	182 per array			3 or more gratings		~10 gratings	~10 gratings
Grating-to-Grating Align’t	2 arc sec	2 arcsec gtg-to-ref. surface		2 arcsec		2 arcsec	2 arcsec
Other Goals	NA	▪ X-ray test atomically smooth groove facet	▪ X-ray efficiency test large area grating for groove quality and uniformity	▪ Grating substrates fab'd w mass production processes applicable to flight gratings		▪ End-to-end X-ray test of grating module with SXT mirror segment	
				▪ Flight representative module structure		▪ Flight like gratings and modules	
				▪ Verify alignment before/after environmental test		▪ Verify alignment before/after environmental test	
TRL	TRL 9	TRL 3	TRL 4	TRL 5		TRL 6	
Technology Gate				◆		◆	

Recent Reflection Grating Technology Achievements

- Very large area (300 mm diameter) gratings with excellent spatial fidelity
- Fabricated off-plane grating with superior profile and efficiency
- Assembly truss has 2 arcsec accuracy, and better than 2 arcsec repeatability
- Thin-foil flatness better than 1 micron on 400 micron thin substrates
- Deformation due to epoxy replication is on the way to being solved with nanoimprint lithography, even for thin (1/2 mm) substrates. Distortion is extremely low.
- "Off-plane" gratings have been demonstrated in a lab test of resolution
- Lab and synchrotron measurements provide quantitative comparison of efficiency for In-plane and off-plane samples

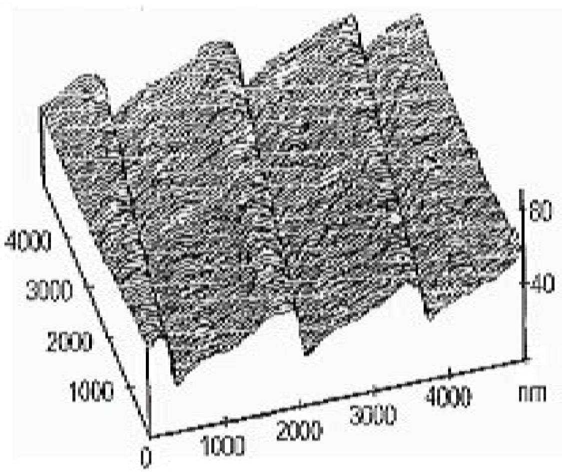
Very Large Area (300mm Diameter) Gratings

Fabricated with MIT 'Nanoruler'

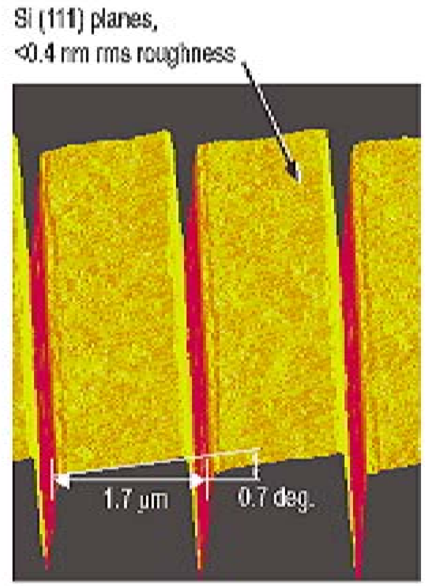


Anisotropic Etching of Si Yields Super-smooth Grating

- **Superior performance for both in-plane and off-plane gratings**



Mechanically Ruled and Replicated
(XMM Grating - Old Technology)

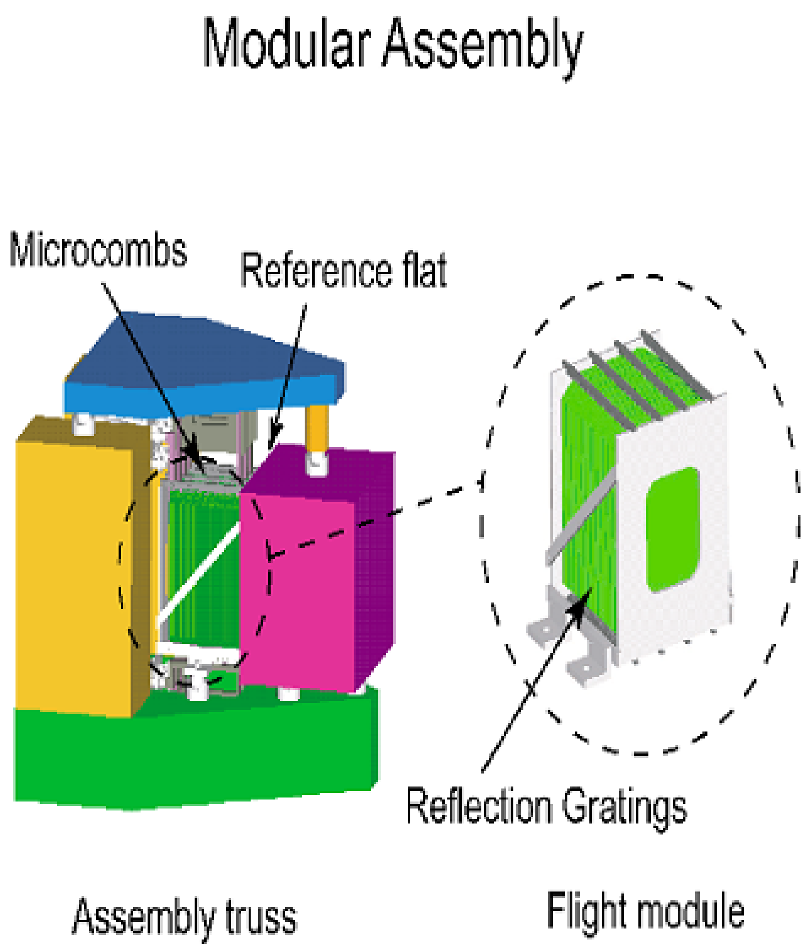


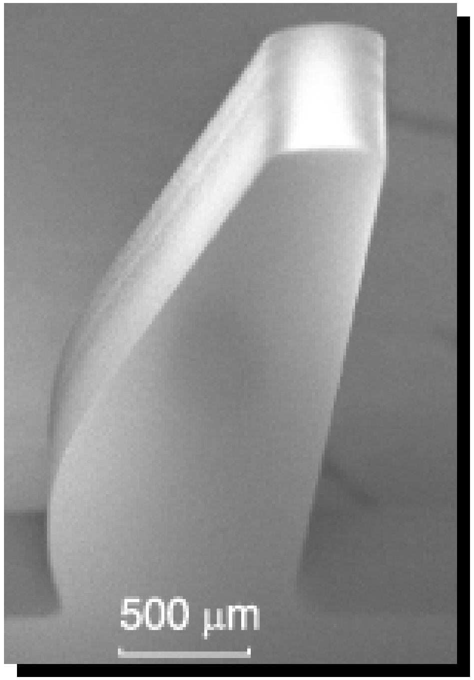
Anisotropically Etched
(MIT Grating - New Technology)

In-Plane (shown above): period = 1.7 μm, blaze angle = 0.7 deg
Off-Plane: period = 0.2 μm, blaze angle ~ 7 deg

Assembly Truss

- **Assembly truss has 2 arcsec accuracy, and better than 2 arcsec repeatability**





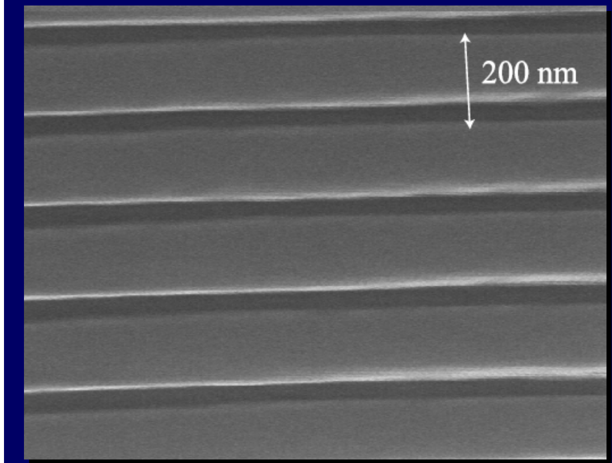
Reference Comb Tooth

Replication with Thermal Cure Nanoimprint Lithography

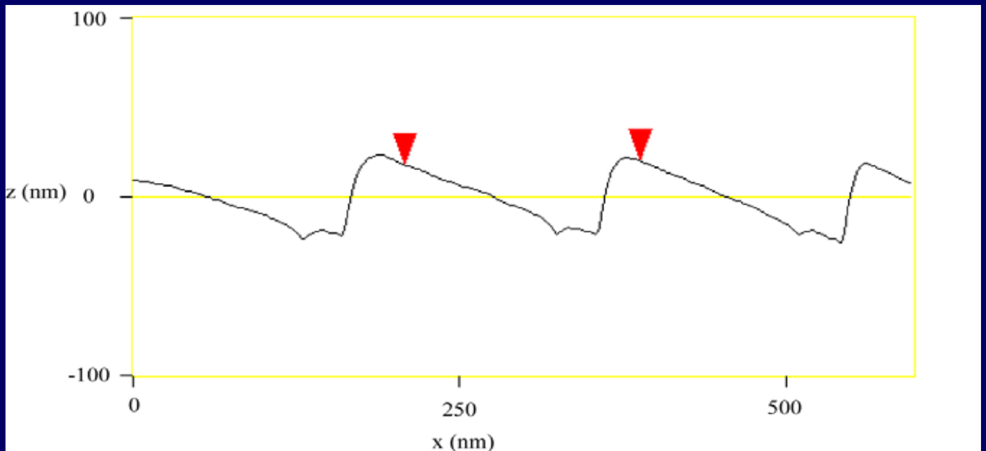
- **Deformation due to epoxy replication is being solved, even for thin substrates**

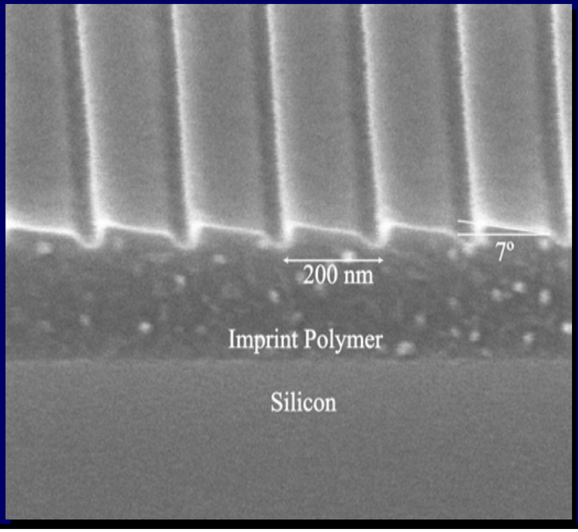
SEM Picture

< .2 nm roughness
Wafer Distortion ~110nm

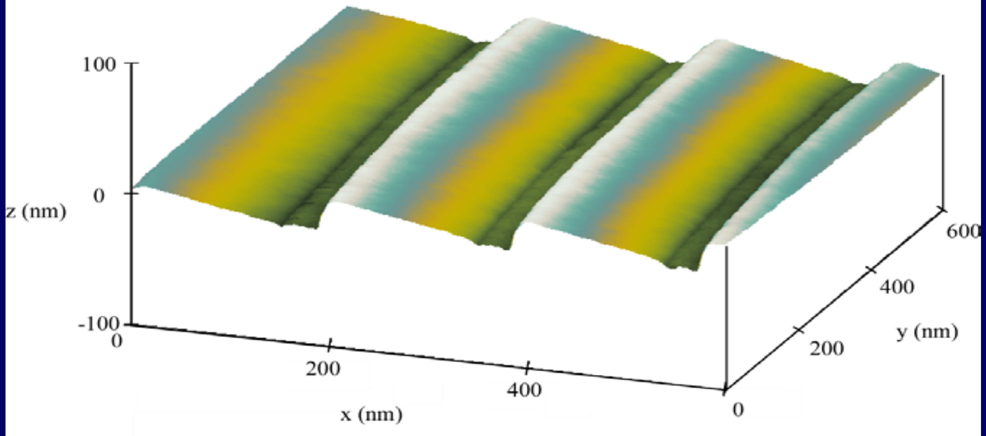


Top view





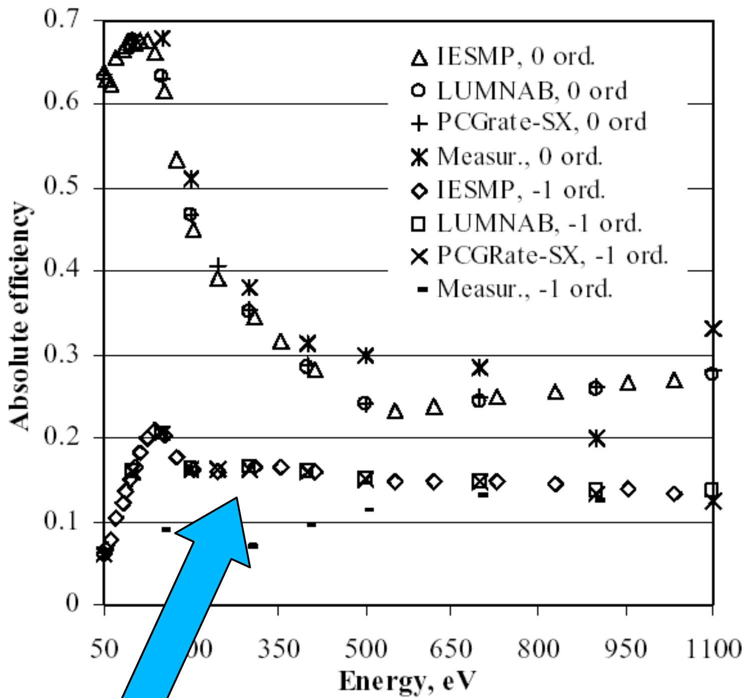
3D view

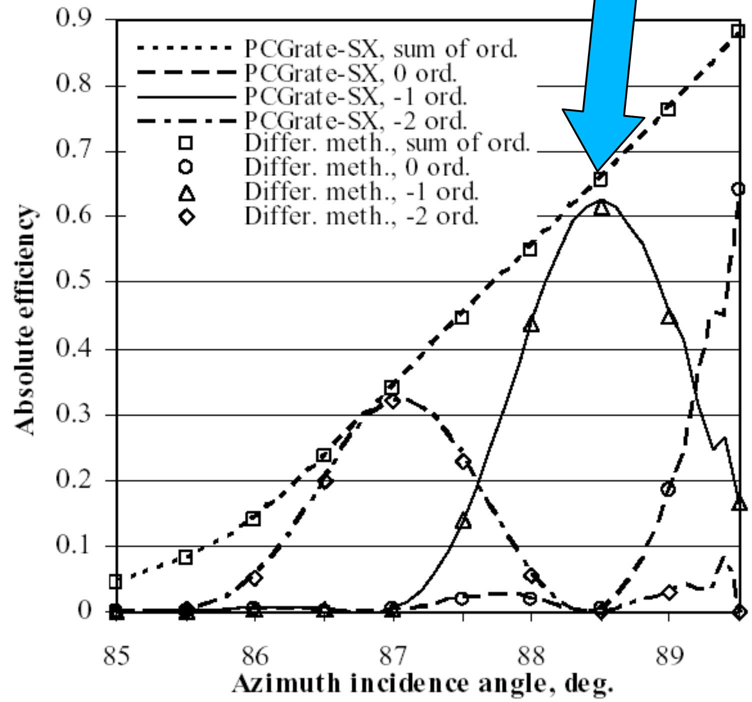


Off-plane Grating Shows Significant Throughput Advantage

L. Goray — SPIE 2003

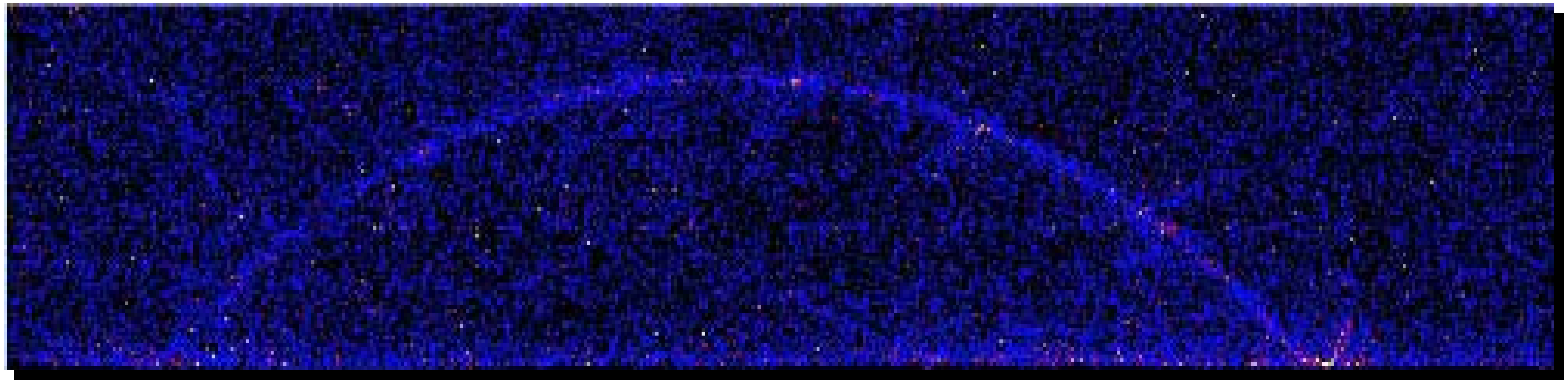
Off-plane 60%





In-plane 17%

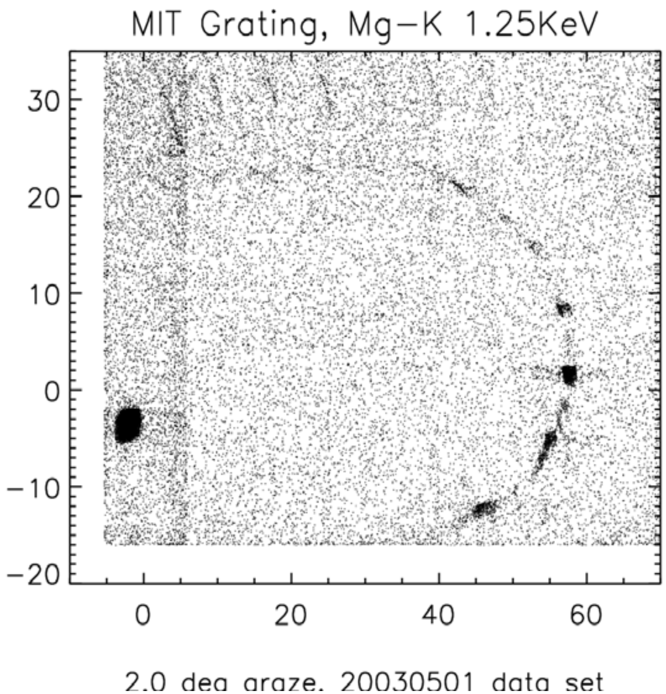
Off-plane Grating Resolution of 500 Demonstrated With 3 Arcmin Telescope



Limited by telescope (dispersion limited):

- **3mm image from hole telescope**
- **0.2mm image subapertured**
- **1m focal length**

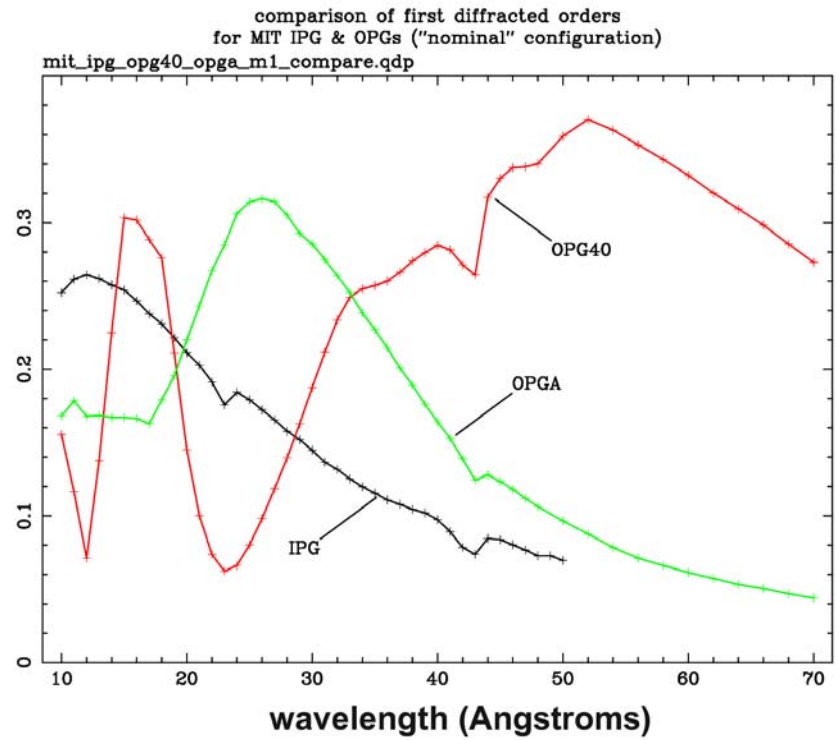
Lab Efficiency Measurements of Off-Plane Grating



	_ (degrees)	Abs. Eff. one order	Abs. Eff. Sum orders	Groove Eff.*
Mg-K	1.35	25%	38%	54%
(1.25 keV)	1.5	28%	40%	59%
	2	9%	27%	48%
Cu-L	1.5	21%	24%**	35%**
(0.93 keV)	2	18%	30%	45%

- **MIT, parallel rulings, 5000 g/mm, blazed 7º**

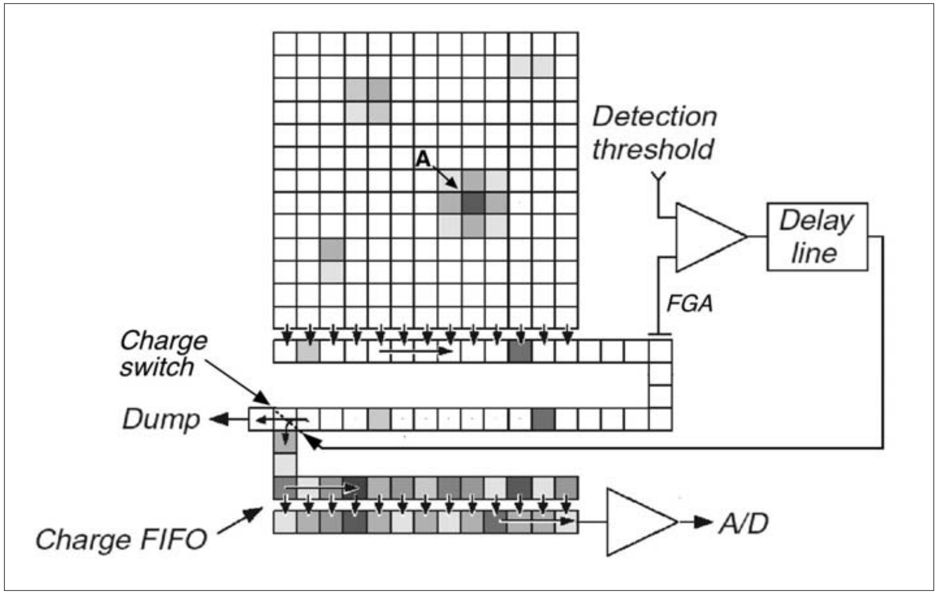
Synchrotron Measurements of Efficiency



RFC Technology Roadmap

Parameter	State-of-the-Art Chandra ACIS	Current	ED-CCD Gen1 Lot1	Test BI CCD	ED-CCD Gen2 Lot1	ED-CCD Gen2 Lot2	Engineering Unit Focal Plane	Flight Requirements
QE at 0.25 keV								
▪ Bare CCD	0.73	0.8	N/A (FI)	0.9	0.9	0.95	0.95	0.95
▪ CCD+OBF	0.15	0.25	N/A (FI)	—	0.8	0.86	0.86	0.86
Device Yield								
▪ FI	0.1	0.8	0.9	0.9	0.8	0.8		
▪ BI	0.02	0.25	N/A (FI)	0.5	0.25	0.25		
▪ Net = FI*BI	0.002	0.2		0.45	0.2	0.2		0.2
CCD Frame Rate (Hz)	0.5	2	10	2	50	50	50	50
EDCCD Config		—	FI	BI	FI, BI	BI	BI	BI
Energy Resolution (eV)								
@1.5 keV	130 (S3-BI)	69 (FI)	70(FI) pred	70(BI)	125 (BI)	100 (BI)	100	100
@0.25 keV	110 (S3-BI)	91 (LTM-BI)	N/A (FI)	52(BI)	125 (BI)	100 (BI)	100	100
Event Reconstruction	3x3, 5x5	3x3, 5x5	3x3	3x3,5x5	3x3,5x5	3x3,5x5	3x3,5x5	3x3,5x5
Array Format	1024^2		512^2	1024^2	1024^2	1024^2	1024^2	1024^2
Focal Plane Complexity	10 chips	48 chips	1 chip	1 chip	1 chip	1 chip	4 chips	13 chips
Radiation Tests			Y	Y		Y	Y	
Environmental Tests							Y	
TRL		TRL3			TRL4		TRL 6	
Technology Gate						◆		

EDCCD: Baseline Sensor

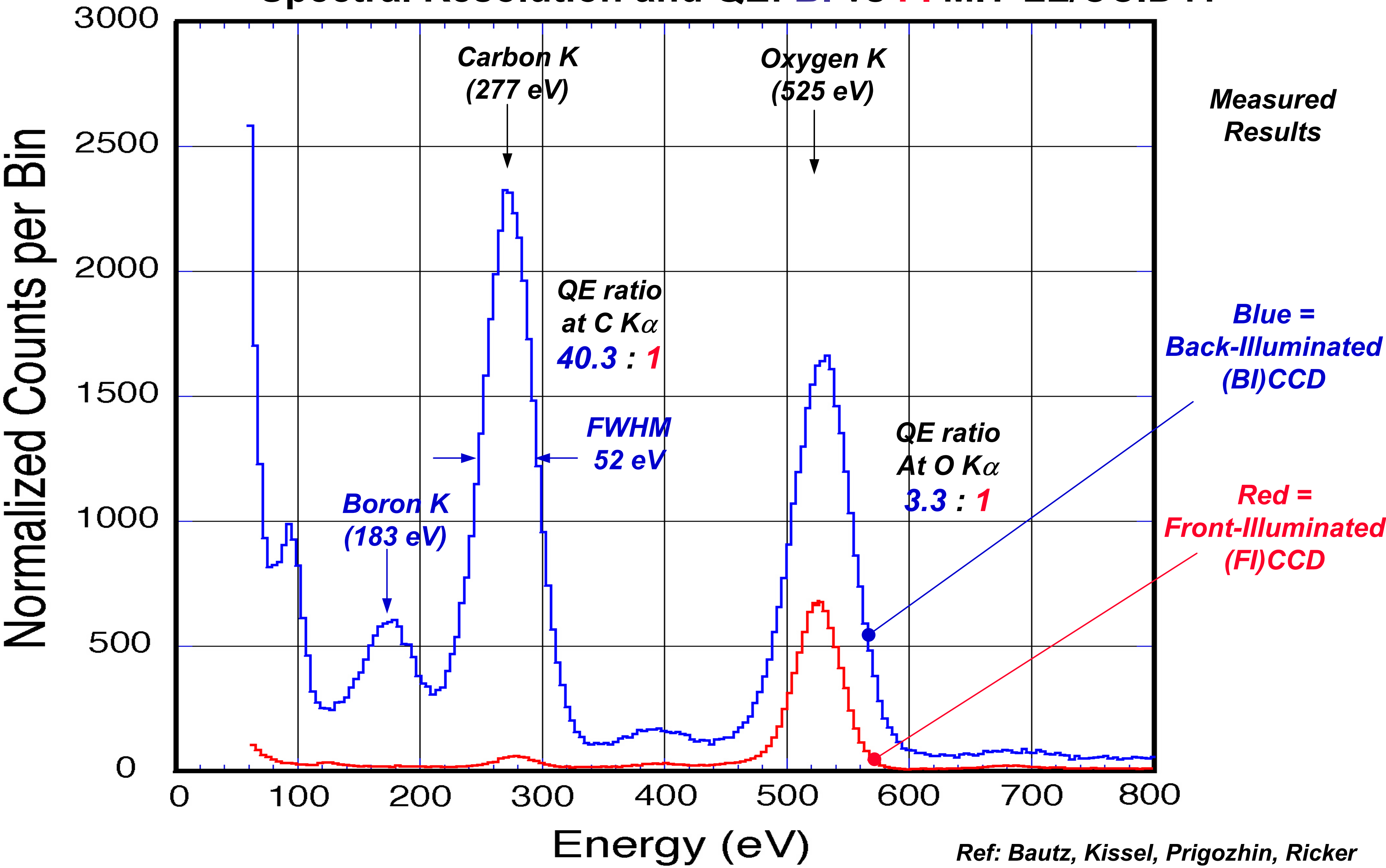


- **System Constraints relief for Con-X**
  - Lower power dissipation at a given frame rate (>100 x less)
  - Enables integrated flight camera testing at room temperature
  - Compatible with broad operating temperature range (~ 0˚ C to -120 ˚ C)
  - Reduced shielding requirement (>10x more radhard)
  - High frame rate: relaxed S/C stability and jitter requirements

- **Event-Driven CCD: Advantages**
  - Pixels are non-destructively sensed, and only those with signal charge are saved and digitized
  - Compatible with high yield BI processes
  - High speed: 100 x Chandra/ACIS (greatly reduced pileup)

- **Additional Advantages of EDCCD**
  - Improved QE for 0.2 - 2 keV band
  - High frame rate (30-50 Hz); thus, can use thinner optical blocking filter (OBF)
  - High yields and reduced risk
    - Conventional MOS CCD processing
    - Compilation of separately-tested innovations
    - Flight-proven (ASCA, Chandra) key elements
      - Parallel register array
      - Low noise floating diffusion output amplifier

Spectral Resolution and QE: BI vs FI MIT-LL/CCID41



Ref: Bautz, Kissel, Prigozhin, Ricker

Next Steps for RGS Technology Development Program

- Investigate polarization effects for off-plane gratings
- Perform test of flight-like off-plane grating configuration (flight-like mirror + single grating)
- Upgrade “nanoruler” to make radial groove and chirped gratings
- Test devices in (event-driven) EDCCD mode
- Radiation damage testing of CCDs

Constellation X

The Constellation X-ray Observatory

Hard X-Ray Telescope (HXT) Technology Development

IPT Lead: Dr. Fiona Harrison
Organizations: Cal Tech /Columbia University /GSFC /MSFC /OAB /SAO

HXT Technology Development Roadmap Summary — Optics

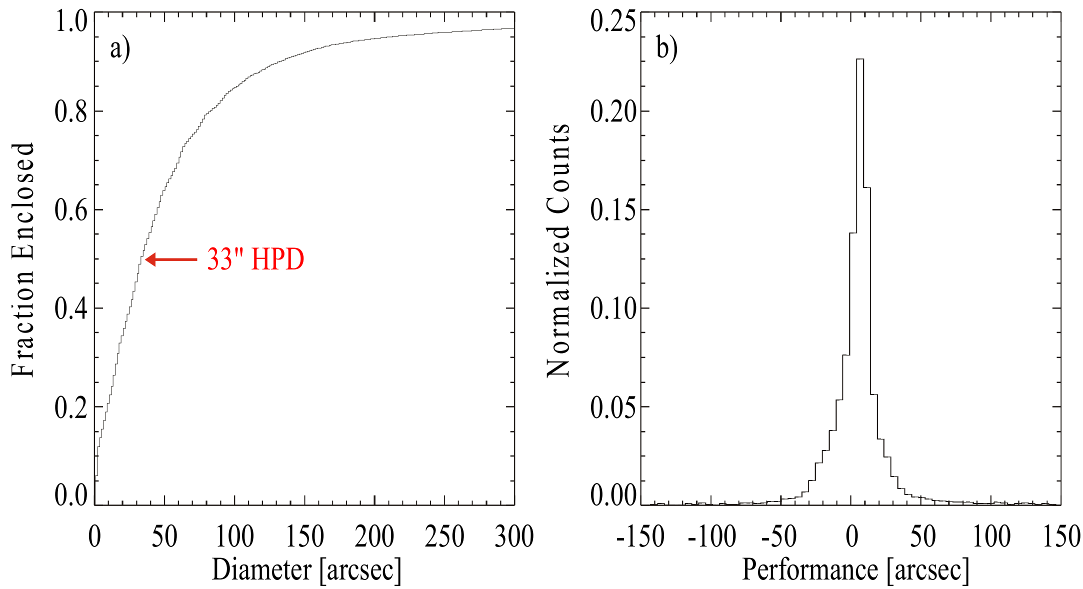
	Technology Selection Prototype		Engineering Prototype
	Glass – Replica Surface	Nickel	Selected Technology
Shell thickness	0.4 mm	0.1 - 0.11 mm	Parameters TBD
Segments/shell	24 (6 azimuthal, 4 axial)	1	TBD
Multilayer	W/Si	W/Si, Iridium	W/Si
Focal length	10 m	10 m	10 m
# Shells	9	5	TBD
Shell diameter / length	10, 22 and 40 cm / 50 cm (P + H)	15 (1 shell) , 28 cm / 43.6 cm	Span full radius range in design
Goals	▪ Demonstrate 30” HPD resolution with replica shells ▪ Demonstrate coating on replica surfaces ▪ Demonstrate required throughput	▪ Demonstrate HPD for thin Ni shells ▪ Demonstrate internal ML coating technique ▪ Demonstrate required throughput	▪ Thermal/vacuum test for stability and robustness of components ▪ Demonstrate performance for representative shells covering entire radius range ▪ Mechanical/vibration test for stability, and to establish isolation requirements
Technology Gates			◆

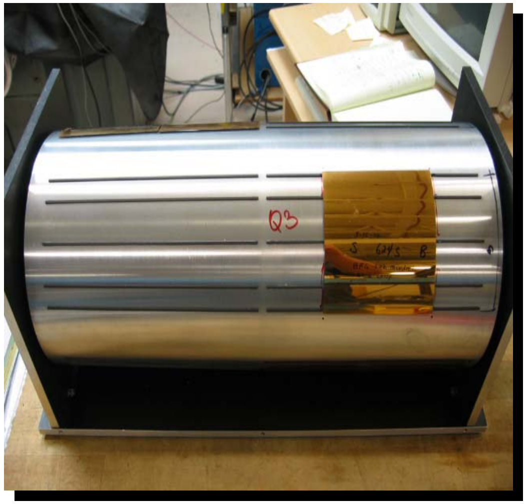
Several Con-X HXT Demo Units Were Built in the Last Year

- **Demonstration of 200 µm, 10 cm glass segments meeting HXT angular resolution requirement and substantially exceeding weight requirement**
- **First mounting of GSFC glass using Columbia University error correcting, monolithic assembly and alignment(EMAAL) technique in Con-X1-1: performance of 300 µm, 10 cm best segment of 33 arcsec near HXT goal – central part of segment ~ 20 arcsec**
- **Study of fundamental issues related to assembly error budget addressed through mounting of replicated and unreplicated GSFC glass establish that EMAAL approach contributing mounting/assembly error < 10 arcsec**

HXT Glass Segment Mirrors

- **GSFC Glass has been mounted with Columbia University error correcting monolithic assembly and alignment and results are encouraging**
  - **Best mounted glass performance 33 arcsec (HPD) for entire segment area**
  - **Axial scans through best azimuthal sections 20 arcsec**
  - **7 segment prototype performance 45 arcsec (HPD)**
  - **Predicted performance based on GSFC interferometry and Columbia laser reflectometry on free-standing samples ~45 arcsec**
  - **10 cm, 300 μm glass segments**

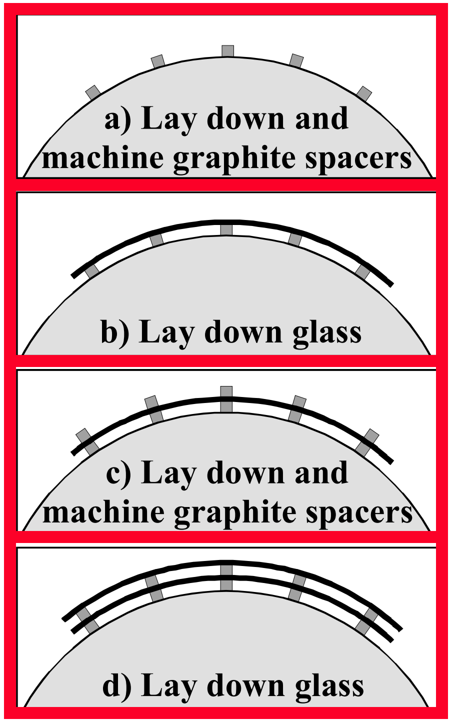




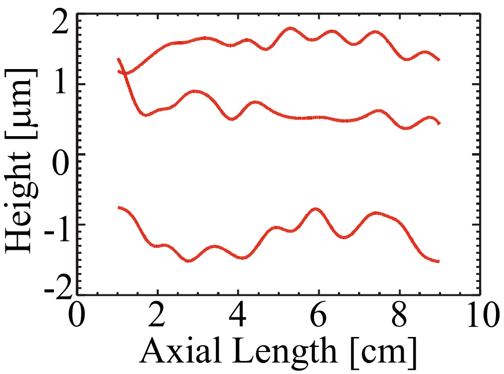
HXT Glass Segment Mirrors

Error Correcting, Monolithic Assembly and Alignment (Columbia University)

- Each spacer layer (upper & lower) is individually machined to the precise radius and angle:
  - Assembly errors do not stack up
  - ~ 8 arcsec assembly error contribution
- X-ray mirror segments are constrained to spacers with epoxy:

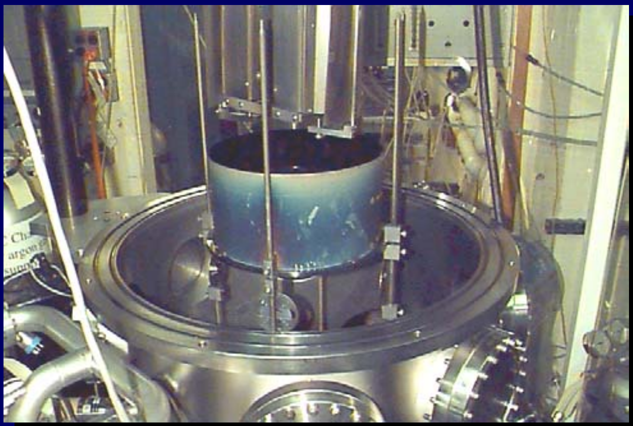


Glass profile above spacers

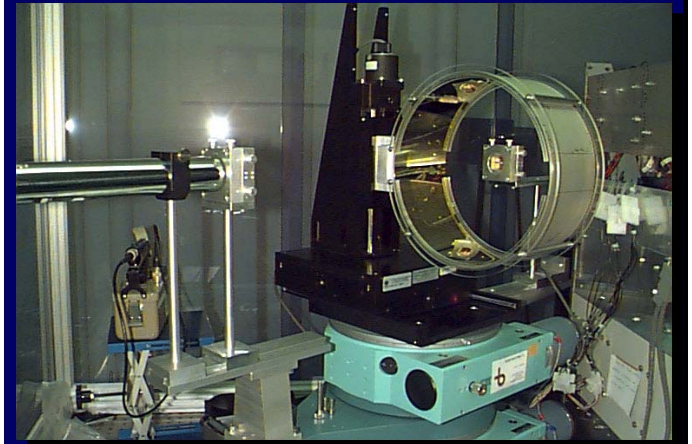


HXT Nickel Mirror Multilayer Deposition

- Completed construction of and tested multilayer deposition chamber and coated several replica shells (SAO)
- Tested coated shells by measuring 8 keV X-ray reflectivity
- Investigated effects of mechanical stress due to multilayer coating
  - Coating over the full 360 deg. of azimuth stress appears to balance
  - This has been established by metrology performed at MSFC upon shells before and after deposition of a multilayer coating
  - Low distortion in a 360 degree coating is in agreement with a the predictions of mechanical model of the effect of stress upon a 100 micron Ni shell



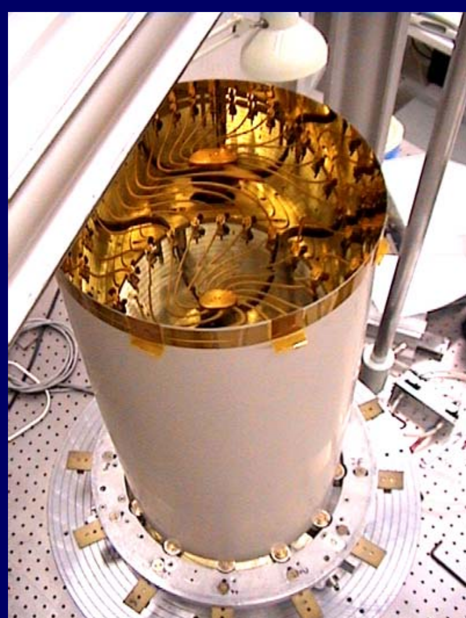
Coating Chamber

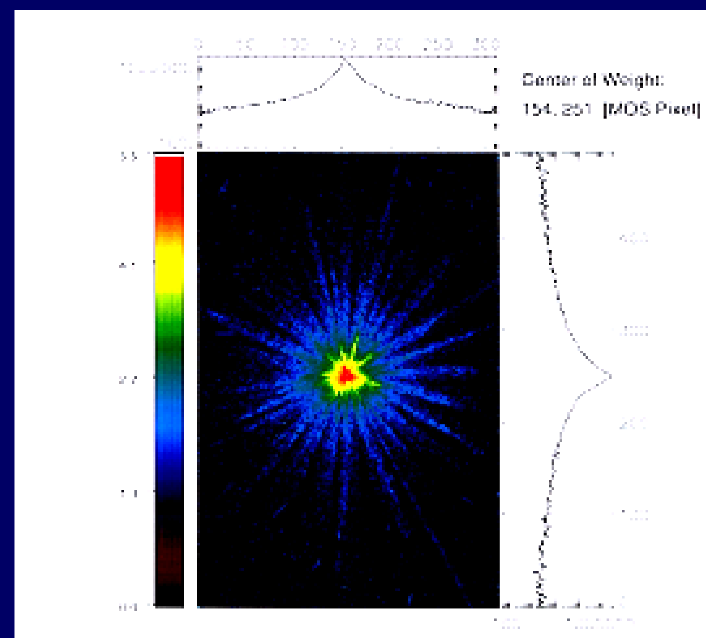


Test Setup

HXT Replicating Lightweight Nickel Mirrors

- **Fabricated mirror shell under supervision of OAB**
  - **Thickness to diameter ration (t/d) is 1/6 SWIFT mirror and 1/3 XMM**
  - **X-ray test of thin shell at MPE Panter facility showed 25 arcsec resolution half power diameter (system requirement for HXT is 60 arcsec)**
  - **These results validate adopting lighter weight mirror shell with smaller t/d ratio**





HXT Nickel Mirror Prototype and Pre-prototype

- Designed and began work on 5 mirror shell Prototype
  - Mandrel production at OAB and MSFC
  - Electroformed two inner shells with surface roughness < 5 Angstroms rms (MSFC)
  - Constructed central support structure (OAB)
- Modified nearest term milestones due to funding reduction
  - The SAO/OAB/MSFC group plans to continue development and testing of a reduced integral shell mirror at a lower level in FY04/05
    - 2 mirror shell pre-prototype, 1 each provided by OAB and MSFC
    - X-ray testing of pre-prototype will take place at the MPE Panter facility

3 Mandrels at OAB in Different Stages of Polishing

1 of 2 Mandrels Being Polished at MSFC

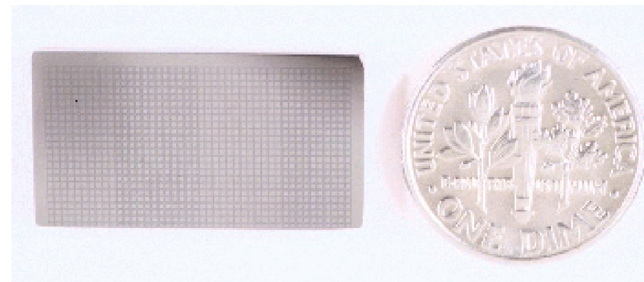
HXT Detector Technology Roadmap Summary

Demonstration Prototypes		Flight Prototype
Sensor	CdZnTe & CdTe	TBD
Format	8 x 8 pixels	24 x 48
ASIC	Redesign of HEFT chip for low threshold	Full-size version of prototype
Pixel size	0.5 mm	0.5 mm
Goals	▪ Demonstrate low threshold for redesigned chip ▪ Evaluate low-energy performance; QE and resolution for two materials	▪ Demonstrate threshold for full-sized chip ▪ Qualify packaging approach ▪ Demonstrate in radiation environment
Technology Gate	◆	

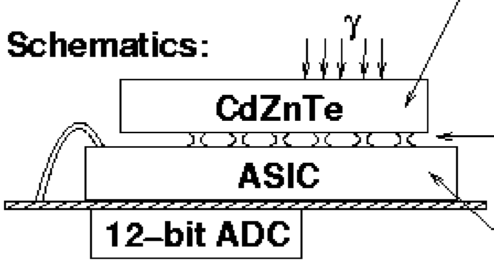
HXT Detector Profile

Acknowledgement:
Hubert Chen (grad student, CIT)

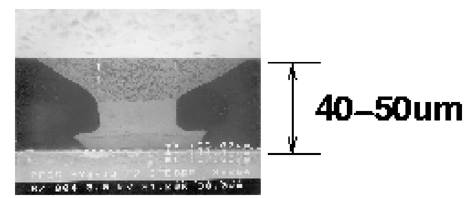
CdZnTe:
single crystal, 13.0 mm x 23.7 mm x 2.0 mm
Anodes: 24x44 pixels, 498–um pitch
30–um gaps, $(468\text{–um})^2$ Pt contacts
Cathode: monolithic Pt



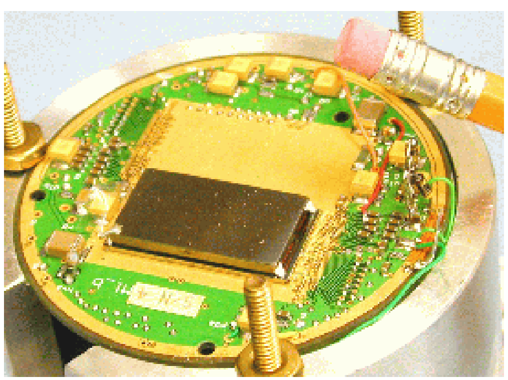
Schematics:



Flip–chip bonded
with stud bump and
conductive epoxy bonds



Custom, low–noise,
low–power ASIC readout,
flip–chip bonded



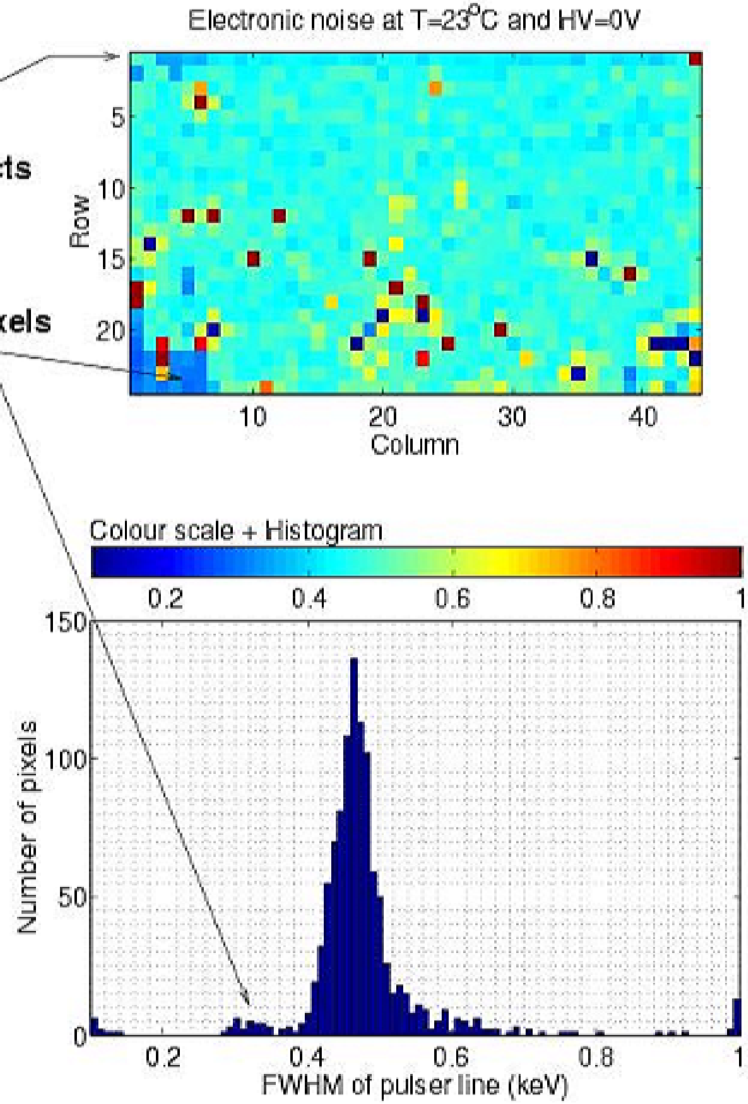
Square sensor area formed by two detectors
with minimal dead area in between

Optimized for operation at 0 C

Characterization — Electronic Noise

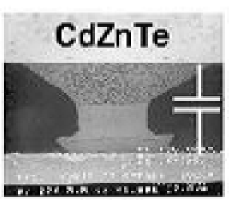
First row:
Narrower contacts
--> lower noise

Unconnected pixels



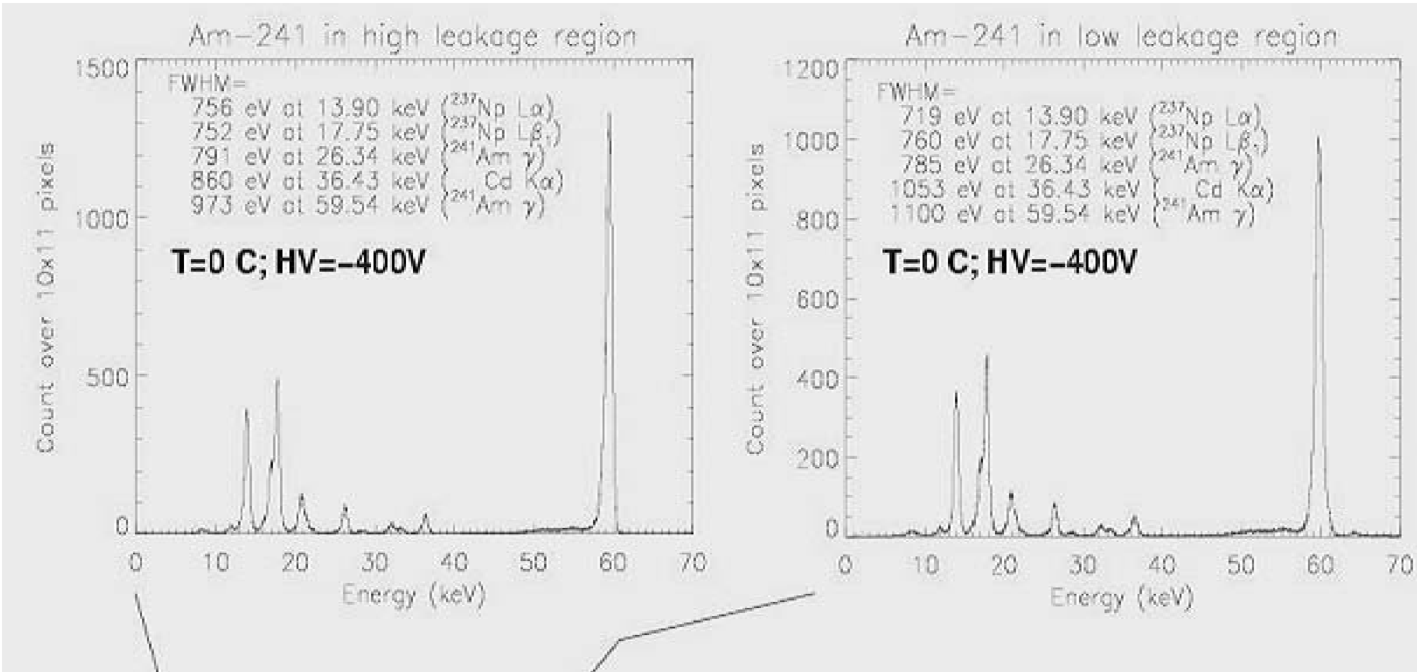
On–chip pulser at each pixel simulates 75–keV spectral line.

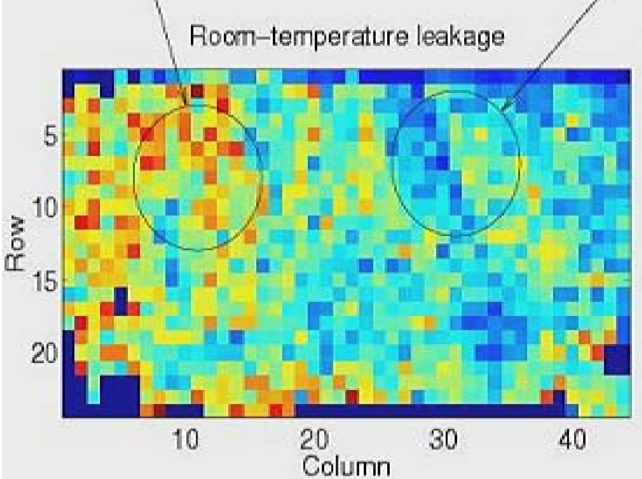
Thermal noise dominated by input capacitance between anode contacts and ASIC



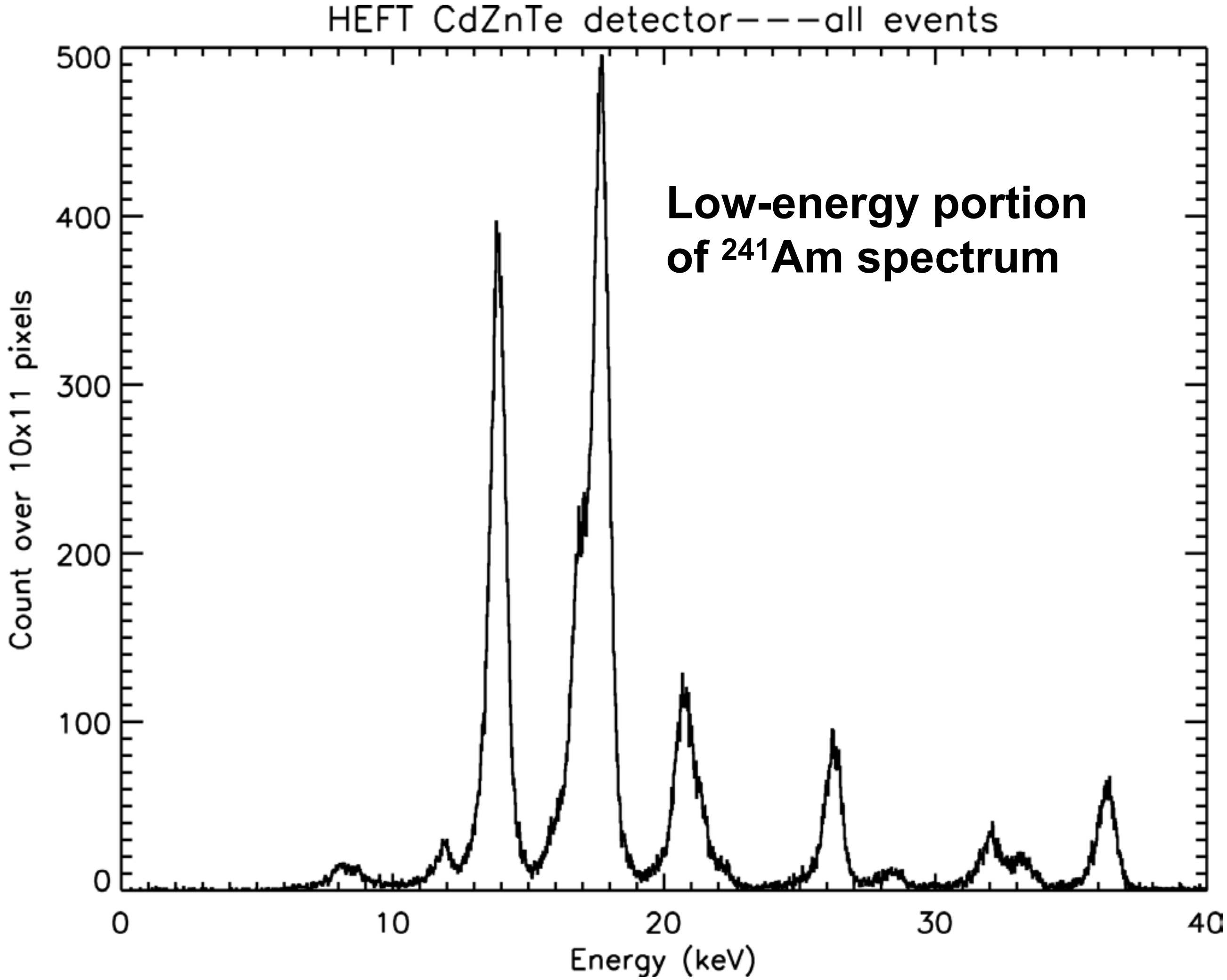
ASIC

Characterization — Spectral Resolution





- Am-241 collimated within circle of 10 pixels in diameter
- Both spectra include all events triggering 1 or 2 adjacent pixels (>90%)
- Low-energy line widths dominated by electronic noise
- High-energy line widths dominated by depth effect
- Leakage not an issue at 0 C


HEFT CdZnTe detector---all events
Low-energy portion of ^{241}Am spectrum
Count over 10x11 pixels
Energy (keV)
0
100
200
300
400
500
0
10
20
30
40

Wrap-Up

- Current budget picture requires change in plans
  - Back off on mission-level implementation activities
  - Use time to define a better mission
- Concentrate on technology development
  - Continue to make progress
  - However, focus will be on component level achievements; progress to system-level milestones is greatly slowed